How to Observe the Sun — SAFELY

# ASTRONOMY®

## Titan Mapped! HST Sees a Hidden World

February 1995 U.S. $3.50
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ICD 08070

VENUS
the New Old Planet

- Capturing Comets With CCDs
- Explore Seven Bright Star Clusters

MEADE
12" LX200
10" LX200
8" LX200

Supplied complete per catalog specifications**:

| | |
|---|---|
| **8" LX200 Schmidt-Cassegrain** | **$2495.** |
| **10" LX200 Schmidt-Cassegrain** | **$2895.** |
| **12" LX200 Schmidt-Cassegrain** | **$3995.** |

Packing & shipping in 48 states: 8"—$105; 10"—$145; 12"—$215.

- **All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.
- For dealer or catalog information see the **Meade Starfinder Reflecting Telescope** ad in this issue.

# LX200
# SCHMIDT-CASSEGRAINS

## Now with *one arc-minute* pointing accuracy and 64,350-object onboard database as *standard-equipment!*

**Meade 8", 10", and 12" LX200 models with standard-equipment High-Precision Pointing™ software now automatically GO TO any input RA and Dec, or to any object in the 64,350-object database, to a pointing precision within one arc-minute!**

**New Meade Version 3.30 software** and high-resolution encoders, used in conjunction with the unique Meade SYNC command, now yield the most precise automatic slewing ever offered in a commercial telescope, an observatory-level of precision and *more than 5 times the precision obtainable with any competing computer-controlled telescope.*

Data entry through the telescope's keypad hand controller may be made either from the onboard 64,350-object library database *(see description at right)* or by inputting the desired object's RA and Dec.

Such precise object-acquisition, selectable during either altazimuth or equatorial operation of the LX200, has numerous important implications for the serious observer:

LX200's with High-Precision Pointing have the HP logo-plate affixed to the telescope's drive base.

☐ Use the GO TO command to *find and center an object in the field of a 4mm eyepiece.*

☐ With other telescopes, acquiring even bright objects on the chip of a CCD imager is generally a chore at best, searching and slewing by trial-and-error until at last the object is positioned on the chip. The LX200's High-Precision Pointing places *every* object on *every* CCD chip *every* time.

☐ Suppose you wish to CCD-image a supernova in an 18th magnitude galaxy—a galaxy invisible *except* through the process of CCD imaging. With Meade High-Precision Pointing, the galaxy can be placed on the chip of every commercially-available CCD unit.

☐ Photographing or imaging faint objects such as the planet Pluto, or comets and asteroids near the photographic limit of the telescope, and plotting the motion of these objects night-to-night, now becomes practical, since the photograph or image may be taken *without the observer ever having seen the object visually,* but knowing that the LX200 will place the object precisely in the telescopic field.

**All Meade LX200 models now include a 64,350-object onboard database as standard equipment.**

Imagine having 64,350 celestial objects at the tip of your finger: 64,350 objects that you can actuate and center in the telescopic field just by entering and pressing GO TO on the hand controller. **More than 6 times the size of object libraries included with competing telescopes,** the Meade 64,350-object library includes an incredible array of phenomena—virtually a lifetime of deep-space study, even for the advanced observer:

| | |
|---|---|
| **12,921** | galaxies from the Uppsala General Catalog; the complete UGC catalog. |
| **7,840** | objects from the New General Catalog; the complete NGC catalog. |
| **5,386** | objects from the Index Catalog; the complete IC catalog. |
| **21,815** | variable stars; the complete listing from the General Catalog of Variable Stars. |
| **15,928** | stars from the Smithsonian Astrophysical Observatory (SAO) catalog of stars brighter than 7th magnitude. |
| **351** | alignment stars for the LX200 telescope. |
| **110** | Messier objects; the complete listing. |
| **8** | major planets from Mercury to Pluto. |
| **64,359** | objects, total |

**SPECIFICATIONS: 8", 10", and 12" LX200's**—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel display on the drive base; manual and electric slow-motion controls on both axes; keypad handheld controller with digital readout display, permanently programmable Smart Drive™, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,350-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC (for field operation from any 12v. auto cigarette lighter plug, use the Meade #1812 Electronic DC Adapter, a 4-oz. unit available optionally); 8 x 50mm viewfinder with crosshairs; 1.25" diagonal prism (8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (8", 10") or giant field tripod (12"); foam-fitted carrying case; complete operating instructions.

*ADVANCED PRODUCTS DIVISION*
**Meade Instruments Corporation**
*World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur*
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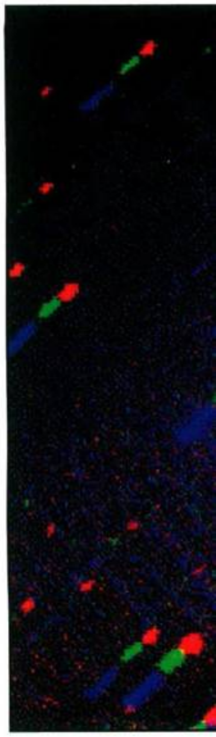
NASA/JPL

MARK KILLION



**76 Seven Easy Star Clusters**

## 32 Magellan Reveals Venus

Magellan's landmark four-year survey of our celestial neighbor unveiled a dynamic geology remarkably different from that of Earth. By Cordula Robinson.

## 44 Hubble Maps Titan's Unseen Landscape

The Space Telescope's keen eye penetrates the smoggy atmosphere of Saturn's largest moon to reveal its largest surface features. By Robert Burnham.

## 48 Compelling Capella

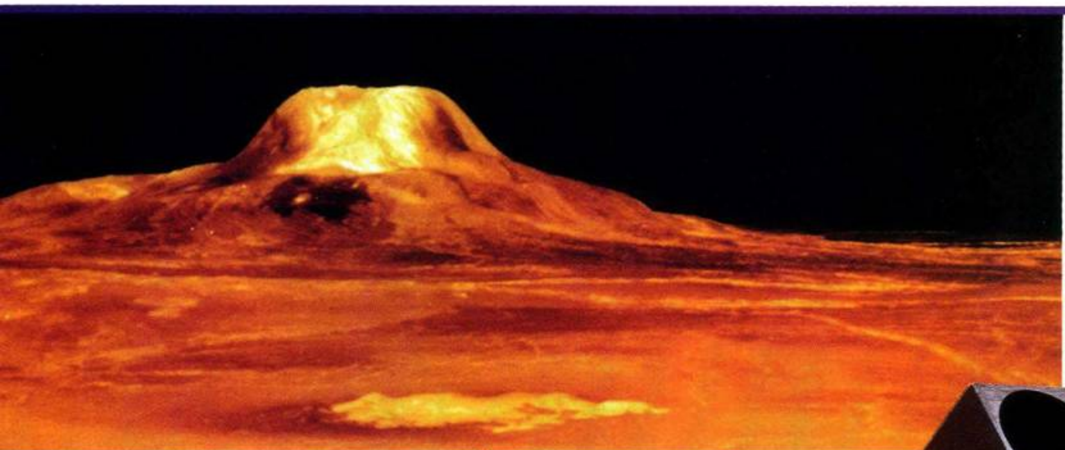
Auriga's brightest star actually consists of four stars — two yellow giants and two red dwarfs. The giants likely foretell the Sun's fate. By Ken Croswell.

## 56 Sky Almanac

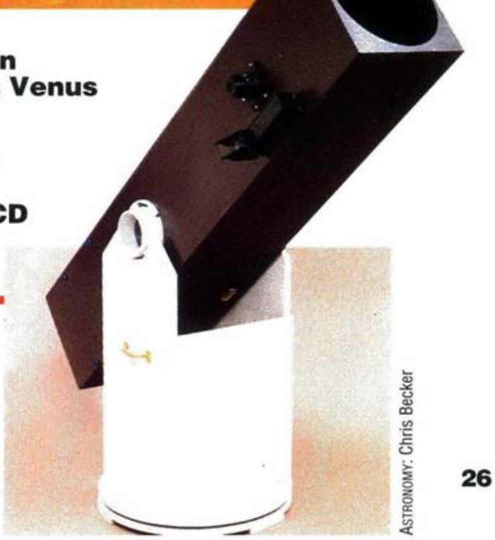
Mars appears bright to the eye and big in the eyepiece throughout February, a month that also sees asteroid Ceres at its best for the year. By Deborah Byrd and Rick Shaffer.

### ON THE COVER

**MASSIVE VOLCANO MAAT MONS** rises 5 km above the fractured plains of Atla Regio in this Magellan radar image. Such images testify to the powerful forces that helped shape Venus. (For more on Magellan's triumphant mission, see page 32.) NASA/JPL image.



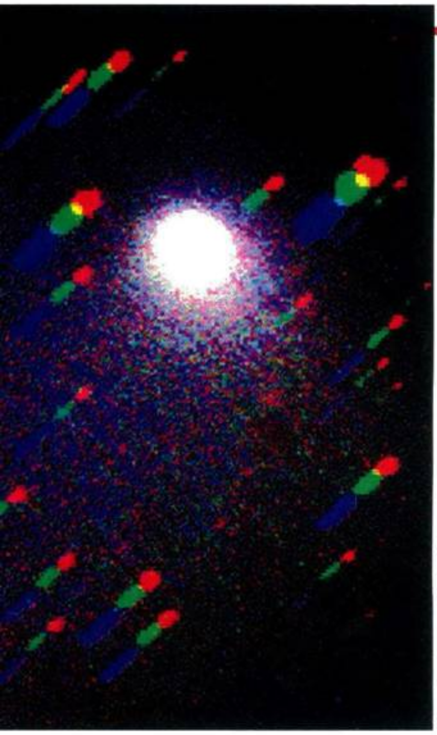
**32 Magellan Reveals Venus**



ASTRONOMY: Chris Becker

**72 Catching Comets with a CCD**

**78 Completing the 10-Inch PortaScope**



Glenn Gombert and John Chumack

Dan Gordon

## 66 Discover the Daytime Star

Sunspots, flares, granules, and more await telescope owners who know how to observe and photograph the Sun safely. By Stephen J. Edberg.

## 72 Catching Comets with a CCD

It isn't easy to capture color images of these celestial visitors as they race across the sky, but this CCD technique shows promise. By Glenn Gombert and John Chumack.

## 76 Seven Easy Star Clusters

Visit some bright but often overlooked clusters that dot the winter Milky Way in Perseus and Cassiopeia. By John Shibley.

## 78 Completing the 10-Inch PortaScope

With the tube and mount finished, it's time to build the mirror cell, add a finder, focuser, and diagonal, collimate the scope, and start observing. By David Bruning.

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- The End of Magellan

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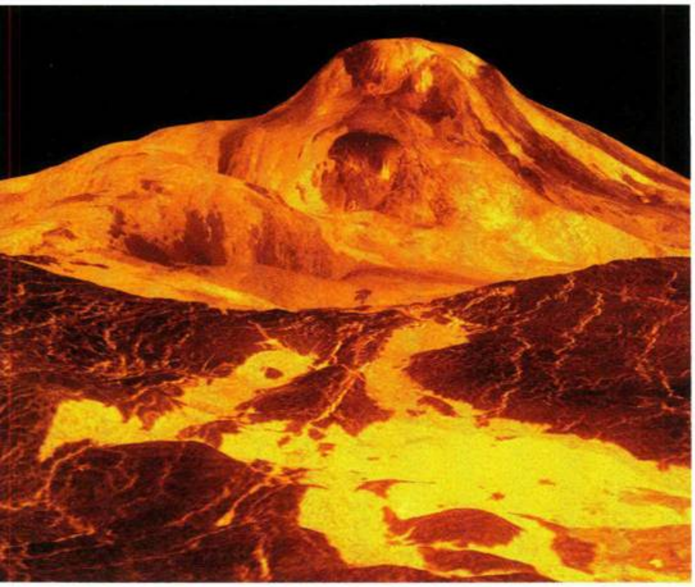
# BEHIND THE SCENES

## The End of Magellan

As NASA's Magellan spacecraft finally augered into the atmosphere of Venus last October, so ended the active part of a stunningly successful mission. Begun over 15 years ago as the Venus Orbiting Imaging Radar mission, Magellan was not a probe into the largely unknown, as were the Voyager craft that carved out new knowledge at Jupiter, Saturn, Uranus, and Neptune. Instead, Magellan built solidly on previous missions, notably the Soviet Union's many Venera probes and the United States' Pioneer Venus. But looking back on Magellan's enormous legacy of data — which is larger than that collected by all deep space missions put together — it's clear that the mission did for Venus what Viking did for Mars. It altered forever mankind's view of a planetary neighbor.

**Maat Mons, Venus**



NASA/JPL

The parallel isn't perfect because Magellan didn't have any lander craft and it certainly didn't bother looking for life. But Magellan did paint Venus' portrait in the same thoroughgoing way that Viking did Mars'. And even well-studied planets can surprise. By systematically mapping Venus at high resolution, Magellan uncovered features about the planet that were unexpected. Yet even more important than discovering new features is the emerging global understanding of Venus, which is the focus of our lead article this month.

As we go to press, news of another foray into the unknown is just breaking. This is the newly determined distances to M100 and NGC 4571 in the Virgo cluster of galaxies. We included a short news note about them in this issue and we'll have a more complete report next month. Watch for it!

Sincerely,

Robert Burnham

Robert Burnham
Editor

# LETTERS

### Power to the People

It's very disheartening to read the complaints in your recent Letters columns from people turning away from astronomy because of the high-tech equipment involved. Such people must not be aware of astronomy clubs. For many years we have introduced the public to the night sky. We do not solicit donations, we do not require people to bring equipment to participate, and we're not eggheads who can't talk on a normal level. (Okay, not *all* of us are eggheads.)

Consider attending a public observing night with almost any major astronomy club in the country. Plenty of telescopes line the ground, waiting to be looked through. Simple telescopes stand next to fancy ones. But that's not the point: It's not which is biggest or has the most bells and whistles that's important. It's the feeling you get when you look through one.

A long night at a star party shows this feeling to be the important benefit from observing. All the other stuff is just details. Check out your local astronomy club. It's usually listed in the phone book and sometimes affiliated with a local observatory or telescope shop. ASTRONOMY's *1995 Observer's Guide* contains a lengthy listing of local groups. We'd love to have you drop by. — *Steve Solon, Denver Astronomical Society, Denver, Colorado*

How can a beginner get into the hobby without spending a fortune? A brief glance through the pages of ASTRONOMY will show that observing is for everyone, from those equipped with binoculars starting at under $100 to Dobsonian telescopes starting at $299 to the most expensive, computer-controlled systems ever created. Besides, the most enjoyable observing comes from naked-eye skywatching. Go outside, look up, and watch the stars!

(continued on page 12)

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The Audit Bureau

# MEADE

## EYEPIECES AND ACCESSORIES

## Series 4000™ Super Plössls

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types for 1994, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

**Super Plössls** (SP; 4-elements; 1.25"; 52°):

| | | |
|---|---|---|
| **6.4, 9.7, 12.4, 15, 20, 26mm** each: | **$87.95** | (3.45) |
| **32mm** (52°); **40mm** (44°) each: | **109.95** | (3.79) |
| **56mm** (52°; 2") | **229.95** | (5.48) |

## Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

**$129.95** (3.60)

## SALE!

### Series 3000 Plössls Save up to 30%!

**Now you can buy Meade *multi-coated* Series 3000 Plössl Eyepieces—the finest moderately-priced eyepieces ever manufactured—at never-before prices!**

*See complete eyepiece description elsewhere on this page.*

*Buy one or buy a dozen!*
*No minimum, no maximum!*

**Series 3000 Plössl 5, 6.7, 9.5, 16, or 25mm:**

*each* **$39.95** (3.45)

*(regularly $46.95 to $57.95)*

**Series 3000 Plössl 40mm:**

*each* **$69.95** (3.79)

*(regularly $79.95)*

This special offer is valid between November 20, 1994 and January 31, 1995, at participating Meade dealers in the U.S.A. and is subject to eyepiece availability.

## Series 4000™ Super Wide Angle

For exquisite wide-angle images at low-to-medium powers, ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8, 18, and 24.5mm are superb complements to the #140 Barlow.

**Super Wide Angle** (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $159.95** (3.49); **18mm: 169.95** (3.69); **24.5mm: 199.95** (3.89); **32mm** (2"): **279.95** (4.78); **40mm** (2"): **339.95** (5.48)

## Series 4000™ Ultra Wide Angle

The ultimate eyepieces; extreme image sharpness over an amazing 84° field.

**Ultra Wide Angle** (UWA; 8-elements; 1.25"; 84°)–**4.7mm: $179.95** (3.29); **6.7mm: 219.95** (3.29); **8.8mm** (1.25"/2"): **269.95** (4.78); **14mm** (1.25"/2"): **329.95** (5.48)

## Series 4000™ #140 2x Apochromatic Barlow Lens

The most advanced Barlow Lens available for commercial telescopes; includes 3-element, air-spaced optics, multi-coated. Unmatched in image resolution, contrast and color correction. Accepts 1.25" eyepieces. Lens dia. 28mm; clear aperture 26mm.

**$79.95** (3.29)

## Series 3000™ Plössls

The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce excellent results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

**Series 3000 Plössls** (4-elements; 1.25"; 50°)

**5, 6.7, 9.5, 16, 25mm** each: **$57.95** (3.45) **Any 2: $52.95** each; **Any 3: $48.95** each; **Any 4 or 5: $46.95** each.

## Series 3000™ Plössl 40mm

A perfect complement to the Series 3000 Plössls at left, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, multi-coated. Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

**$79.95** (3.79)

**Series 4000 Photo-Visual Color Filters** (1.25")—Made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

**#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue**

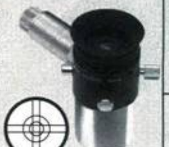
| | | |
|---|---|---|
| each | **$14.95** | (2.29) |
| **Moon Filter #ND96**–Reduces brightness by 87%. | **16.95** | (2.29) |
| **Set #1**–4 filters: #12, #23A, #58, #80A | **54.95** | (2.98) |
| **Set #2**–4 filters: #11, #25A, #47, #82A | **54.95** | (2.98) |
| **Set #3**–4 filters: #8, #21, #38A, #56 | **54.95** | (2.98) |
| **Sets #1 & #2**–8 filters | **99.95** | (3.45) |
| **Sets #1, #2, & #3**–12 filters | **144.95** | (3.79) |

#911B
#910B
#908B
#911N
#910N
#908N

**Series 4000 Nebular Filters**—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

| | | |
|---|---|---|
| **#908B**–Threads into 1.25" eyepieces, 26mm dia. | **79.95** | (2.98) |
| **#910B**–Threads into 2" eyepieces, 44mm dia. | **119.95** | (3.29) |
| **#911B**–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. | **99.95** | (3.29) |
| **#908N**–Threads into 1.25" eyepieces, 26mm dia. | **89.95** | (2.98) |
| **#910N**–Threads into 2" eyepieces, 44mm dia. | **129.95** | (3.29) |
| **#911N**–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. | **119.95** | (3.29) |

## World's Most Advanced Illuminated Reticle Eyepiece



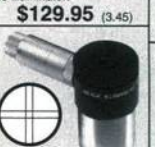
**Series 4000 Plössl 9mm,** with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. **Internal batteries included.** Multi-coated optics. Bullseye reticle. 1.25"

**$149.95** (3.45)

**Series 4000 Plössl 9mm**—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

**$129.95** (3.45)

## MA 12mm Illuminated Reticle Eyepiece



Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. **Batteries included.**

**$99.95** (3.45)

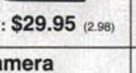
**MA 12mm**—Same as above but with cord and plug for Meade telescopes with power panels, in place of wireless illuminator.

**$79.95** (3.45)

## 2" Diagonal Mirror

**#929:** Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **$99.95** (3.79)

## Camera Adapters (1.25" & .965")



Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

**.965": $27.95** (2.98) **1.25": $29.95** (2.98)

## Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

**$39.95** (2.98)

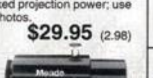
## Tele-Extenders

TELE-EXTENDER

For Eyepiece-Projection photography with any Meade or Celestron SCT. Threads on to any eyepiece-holder. Use with T-mount for your camera.

**Basic Tele-Extender:** *(above)* Fixed projection power; use with eyepiece for lunar and planetary photos.

**$29.95** (2.98)



**Variable Tele-Extender:** Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece.

**$39.95** (2.98)

## T-Adapters for SCT's

For Prime Focus photography with any Meade or Celestron SCT. Use with T-Mount for your 35mm camera.

**$26.95** (2.98)

## 2x Telenegative Barlow (1.25")

**#122:** Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

**$47.95** (3.45)

## 2x-3x Variable Barlow (1.25")

**#127:** Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25"

**$59.95** (3.45)

## 2x Short-Focus Barlow (1.25")

**#126:** Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

**$47.95** (3.45)

## Modified Achromatic Eyepieces

An improvement on the traditional Kellner design, these 3-element Modified Achromatic eyepieces give sharp, faithful, well-corrected images of the moon, planets, and deep-space at an economical price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (2.98)

## HOW TO ORDER

- Prices shown are suggested USA mail-order retail prices and do not include any applicable sales taxes.
- Suggested shipping and handling charges to the 48 states by UPS or US Mail shown in ( ) next to each price.
- Meade accessories may be ordered from any Meade Advanced Products Dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

**ASTRONOMICS, Norman, OK.**
**Orders: 800-422-7876; Info.: 405-364-0858.**

**CALIFORNIA TELESCOPE CO., Burbank, CA.**
**Orders: 800-843-4780; Info.: 818-505-8424.**

**CITY CAMERA, Dearborn, MI.**
**Orders: 800-359-5085; Info.: 313-846-3922.**

**FOCUS CAMERA, Brooklyn, NY.**
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■ For further information call Meade Instruments at 714-756-2291 or contact one of these authorized mail-order dealers:

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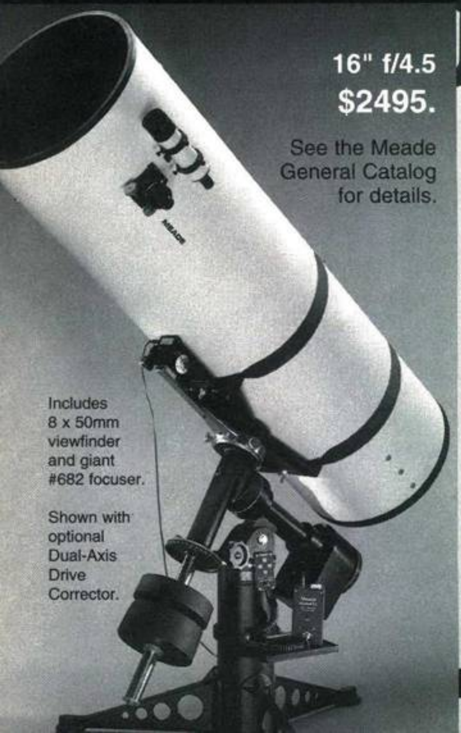

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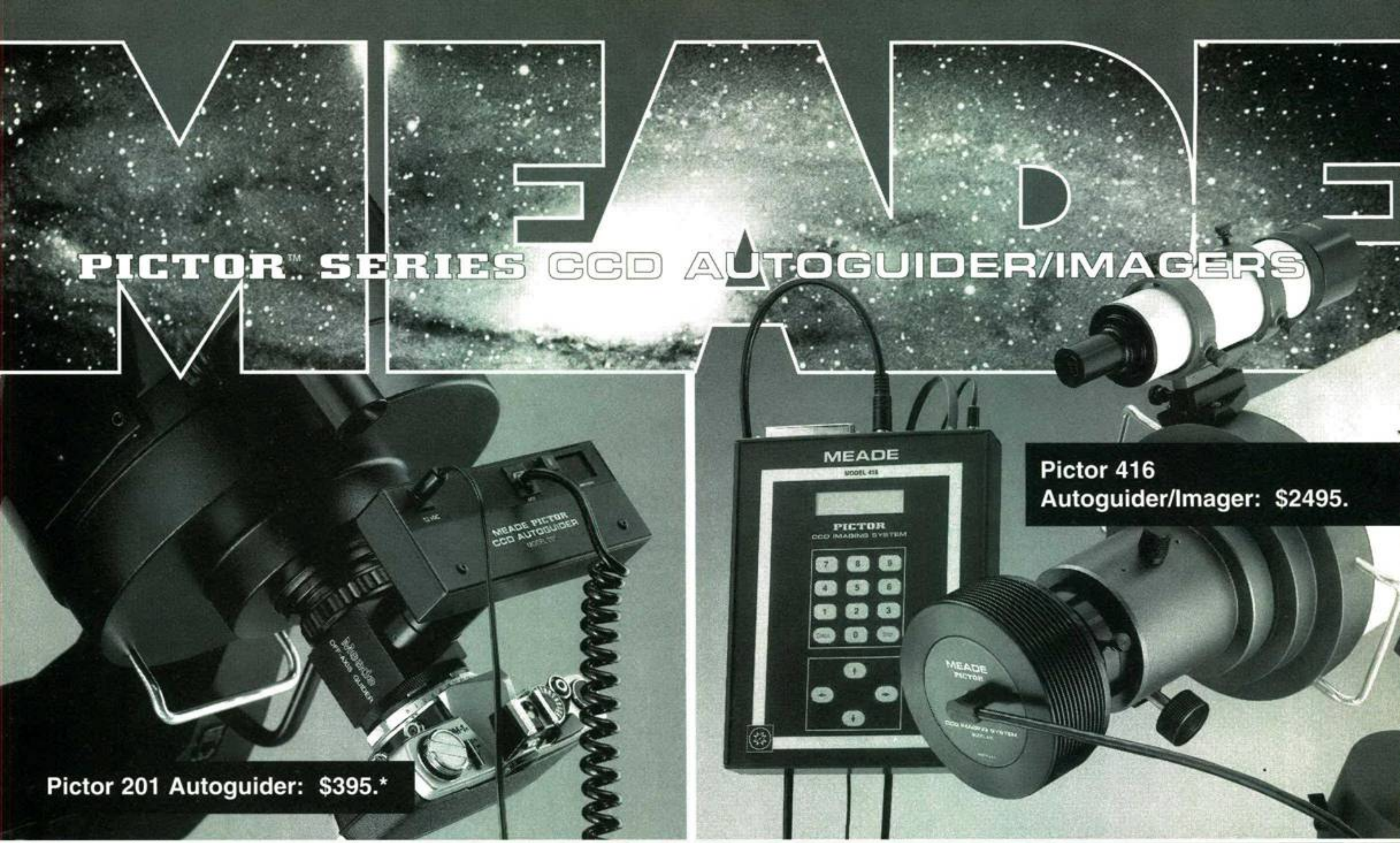
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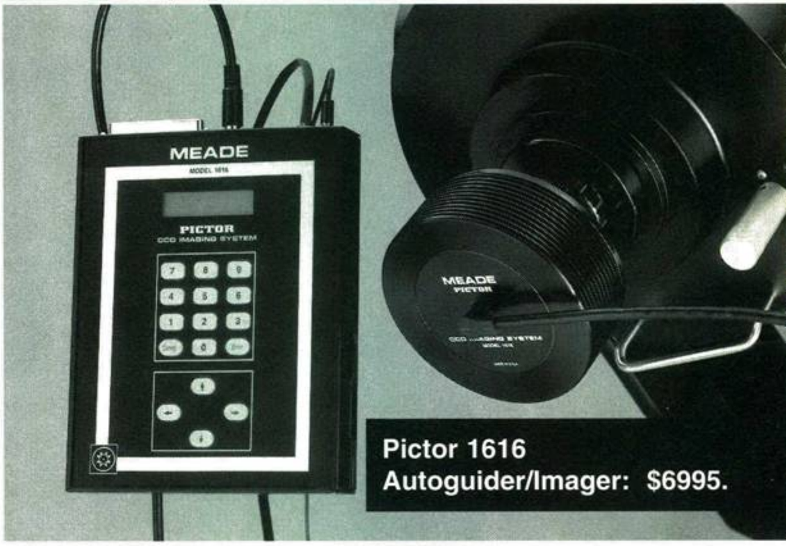
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# LETTERS

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Some day I'll get a 6-inch scope. Until then, I'll delight in viewing the sky with my 7x50 binoculars, a pair of 10x80s I can borrow, the 4-inch refractor at Mt. Cuba Astronomical Observatory, or a 12-inch reflector belonging to the Delaware Astronomical Society. Keep looking up! — *K. Lynn King, Secretary, Delaware Astronomical Society, Wilmington, Delaware*

### Consider It Tabled

Thanks to Deanna Dagilis for her article "Build a Table for Your Star Charts" (May 1994). By using the article I was able to construct an observing table that has helped me to find a number of objects such as M57 in my 4.5-inch scope.

Craig Fernholz

I made some modifications. I took out the 3/4" threaded unions. The silver lining on the bottom of my table was made from scraps from an old screened porch. It is cut down in the middle so I can stick papers or pencils in it. Thanks again. You've helped a 14-year-old boy see the stars better. — *Craig Fernholz, Madison, Minnesota*

### Better Black Holes

Barry Parker's article on black holes (October 1994) is sadly outdated. In 1992 two new black holes were discovered. A binary system in Musca is now thought to be virtually identical to A0620; a British and Spanish group found the compact object in V404 Cygni must have at least six times the mass of the Sun, making it a more convincing black hole candidate than any of the objects discussed in the article. These discoveries were widely reported in the media, including ASTRONOMY (July 1992).

Since 1992, the Compton Gamma-Ray Observatory has discovered four more gamma-ray novae with characteristics similar to A0620, Nova Muscae, and V404 Cygni. When these sources return to quiescence, it seems likely that they too will be revealed as black holes.

So the answer to Parker's question, "Where have all the black holes gone?" is that in terms of their radiation, they appear to be transient sources — the black hole eats its companion one piece at a time, shines brightly for a year or two, and then settles back to digest its meal in obscurity for many decades. — *Charles Bailyn, Dept. of Astronomy, Yale University, New Haven, Connecticut*

### Naming the Moon

Why does our Moon not have its own name? — *Jason Luiz, Union City, California*

*— The proper name of our natural satellite is the Moon and it should always be capitalized. The 60-odd natural satellites of the other planets, however, are called moons (in lower case) because each has a proper name, such as Deimos, Amalthea, Hyperion, Miranda, Larissa, or Charon.*

*In some science fiction works and poetry, you'll find the Moon being called Luna (its Latin name) or even Selene (Greek), but these have made little headway in ordinary usage.*

### Corrections

In the September issue, on page 82, the line "members of the Chappaqua and Erie Astronomical Society" should read "members of the Chautauqua and Erie Astronomical Society." Our apologies.

The address for the Association of Lunar and Planetary Observers in *Observer's Guide 1995* should have read: P.O. Box 143, Heber Springs, AR 72543. Harry Jamieson, the membership secretary, can be reached at (501) 362-7264. The group has about 600 members.

*Practical Astronomy — a User-friendly Handbook for Skywatchers* by H. Robert Mills (Astronomy Books, September 1994) is distributed domestically by Paul & Co. Publisher's Consortium. ☐

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*ASTRONOMY welcomes feedback. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187, or on the Internet, use 72000.2704@CompuServe.com. Letters may be edited for length and clarity.*

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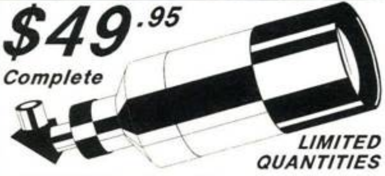

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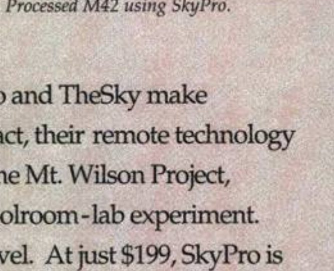

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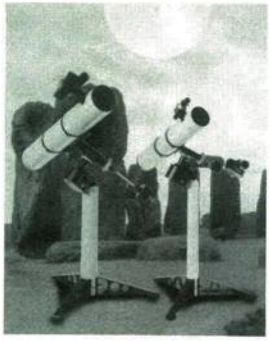

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ASTRO FORUM

# Big Eyes on a Lone Star Night

## by John Shibley

They call it the Ultimate Star Party — ultimate because it draws observers with really big scopes who want to do nothing but observe. No talks, no vendor tables, no lines to look at M13 . . . just hard-core, look-at-that-faint-fuzzy observing. Set high atop a plateau in the Davis Mountains of southwest Texas, this year's star party has three 36-inch telescopes, four 25s, six 20s, and a slew of 12- to 18-inchers. I've escaped my light-blitzed, southeast Wisconsin skies with a pair of 14x100 binoculars. What will two eyes working with twin 4-inch "telescopes" really see in these dark, Texan skies? I'm dying to find out, but like everybody else at this party, I'm seduced by aperture — large aperture. So I bug my neighbor Bob Ross for a look through his giant scope.

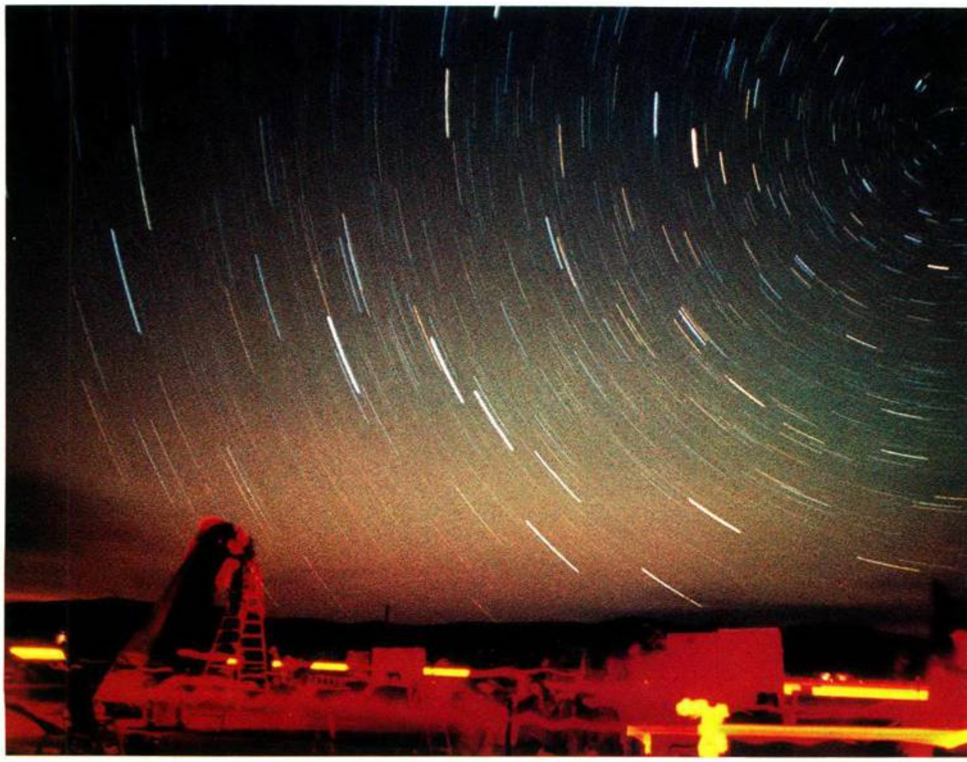
Bob comes from Colorado with his 36-inch f/5 Dobsonian. Always looking to reduce the number of trips up and down his observing ladder, he uses binoculars to survey star atlases on his desk. "It's improved my efficiency 30 percent," he cheerfully volunteers. Ask him for a peek at any "top 40" deep-sky object and the exchange is liable to go along these lines:

"Bob, think we could look at Stephan's Quintet?"

"Naw, John, I'm cracking this Abell galaxy cluster tonight."

The clock drive for Bob's scope lies somewhere deep in the frontal lobe of Bob's brain, and tonight it's going to nudge this 15-foot-high monster scope along as Abell 119 rises in the east, transits, and sets in the west. Bob's life goal: To see every object listed in both volumes of *Uranometria 2000.0*. Back home, when the Moon's out, he uses a 15-inch Clark refractor to catalog lunar domes.

Alabama trauma surgeon Bob Haas also observes Abell galaxy clusters with a 36-inch scope, but unlike the other Bob he's often sidetracked by requests to look at easier-to-spot objects, say, in the 11th-magnitude range. The cool desert night forces me to dress in Wisconsin layers. Bob, though, is clad only in shorts and a tee-shirt. He keeps warm — dare I say overheated — by man-handling his scope from object to object.



"Anyone for M57?" his voice rings out over the star party din. Nearby observers, those who labor under the heavy obligation of having to look for faint fuzzies, can hardly believe their ears. For Haas, every target promises the excitement of a trip to Disneyland, be it an elusive UGC object or the Ring Nebula in Lyra.

"You really ought to look at this. There are extensions all over the place tonight!" Some gray forms saunter over to the ladder's base, almost begrudgingly. I take my turn at the eyepiece by climbing Bob's 15-foot ladder. Up, up — the rungs seem to keep coming — until on the top step I stand swaying in the wind, my mind calculating whether the shroud on Bob's behemoth will break the impending fall. Then I see it.

Bear in mind that the famous planetary nebula in Lyra looks great in any scope over four inches, but in a 36-inch it's, well, a cosmic experience. Surrounding the donut-shaped ring are faint tendrils, and spread across the hole is a mottled sheen of light through which the nebula's 15th-magnitude central star shines. Bright portions of the ring are an electric blue-green. Looking away for a fraction of a second, I can see a dull gray after-image burnt into my retina. My eyes water, from wind or wonder, I'm not sure. Haas senses my reaction and lets out an Alabama giggle: "Time's up, buddy. Let someone else have a look."

While making my white-knuckled descent, I glance in the direction of Houston's Larry Mitchell, who has the party's third 36-inch. Last year Larry's wimpy minivan was barely able to haul his scope up the plateau. This year he comes in style, armed with a Lincoln Continental — not for the luxury, but for the brawn a 400-cubic-inch engine can offer on mountain roads. Matching the power of his scope-mobile is Larry's keen mind. Many veteran observers consider it a sport to try to stump this guy on

**TEXAS SKIES SMILE** down upon a field of light buckets. Tail-lights mark the departure of tired but satisfied amateur astronomers.

All photos by John Shibley, ASTRONOMY

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deep-sky trivia. Ask him for stats on any obscure galaxy cluster (I tried one that's in the nape of the Horsehead Nebula's neck), and he'll just roll his eyes up into their sockets and do a data dump. (All this without the benefit of mind-expanding dietary supplements.)

There is one mystical substance making the rounds at this year's USP: bilberry pills. During the Battle of Britain, legend has it, Royal Air Force Spitfire pilots took these pills to enhance their night vision. The thinking goes that what worked for pilots defending the Realm against Nazi aggression surely ought to work on photon-starved deep-sky observers under dark, Texas skies. Many USPers claim a better than one magnitude improvement in visual acuity. I pop a couple and really don't notice a difference. They're found at any health food store, if you want to give them a try.

**MIGHTY ORION** clears a distant mountain ridge. Soon this 36-inch Dobsonian will be sampling light from M42, the Hunter's glorious nebula.

Sheryl Johnson and Debbie Serle, who hail from a state that made health food respectable, sell the stars for a living to schools throughout Southern California. Their business, "Adventures in Astronomy," presents school assemblies and star parties to teachers and students in kindergarten through university. Over *the past five years, they figure close to* 100,000 people have traipsed up their

*(continued on page 20)*

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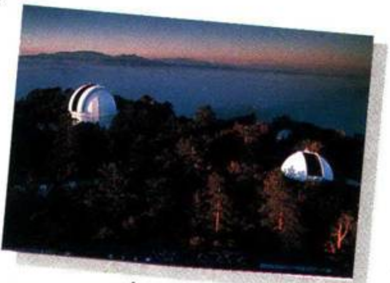

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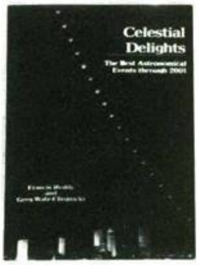
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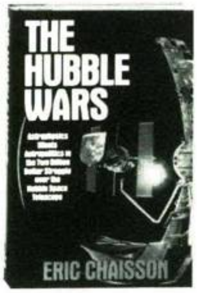
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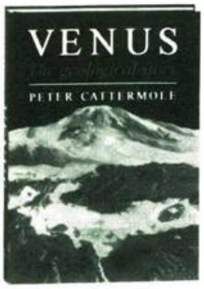
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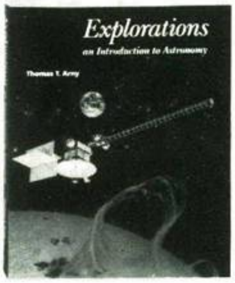
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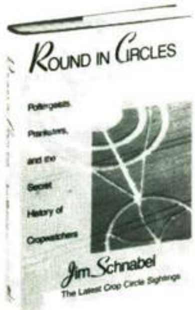
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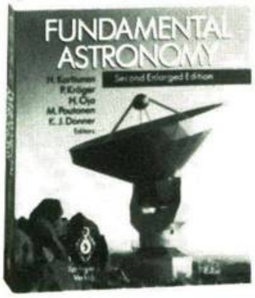
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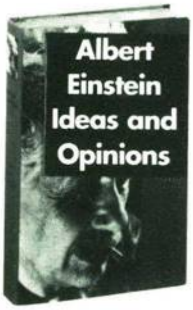
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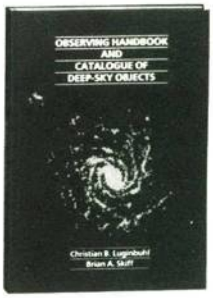
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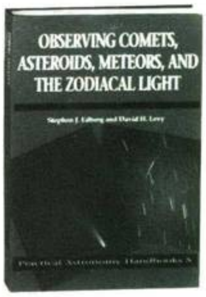
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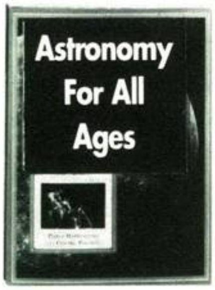
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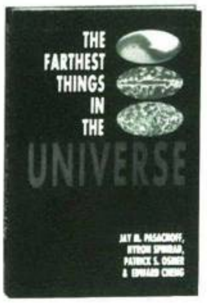
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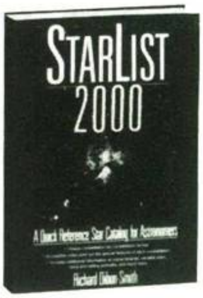
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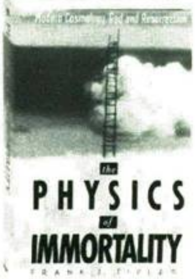
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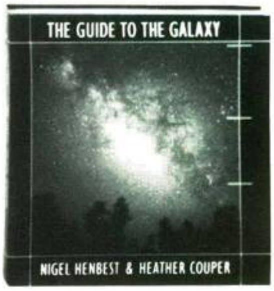
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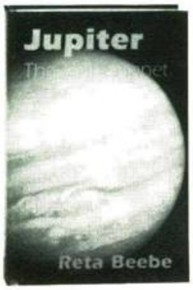
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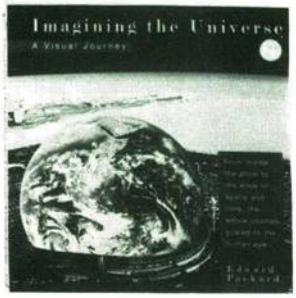
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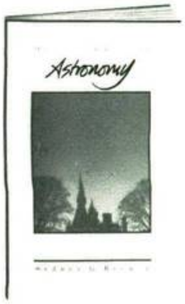

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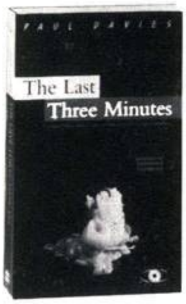
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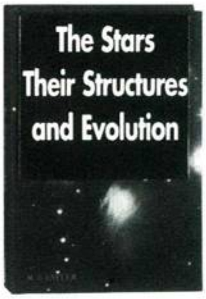
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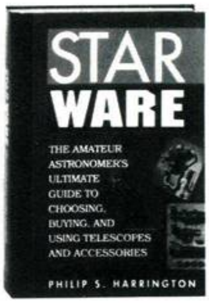
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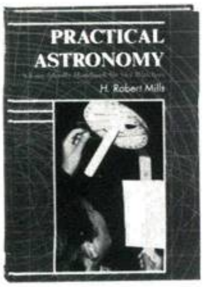
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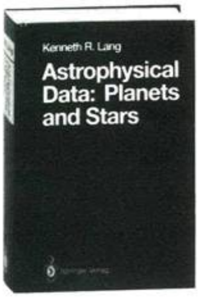
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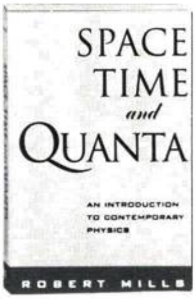
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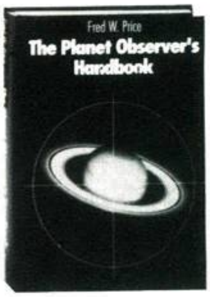
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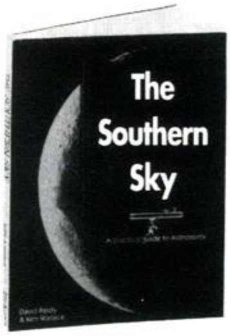
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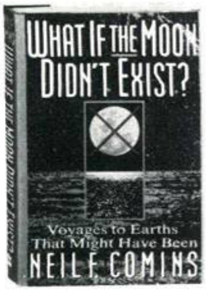
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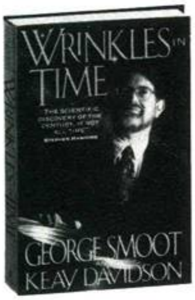
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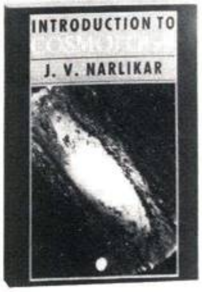
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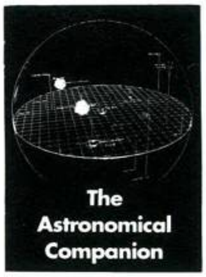
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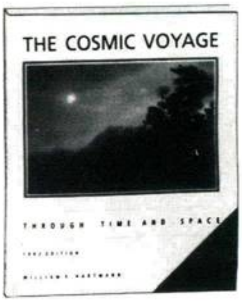
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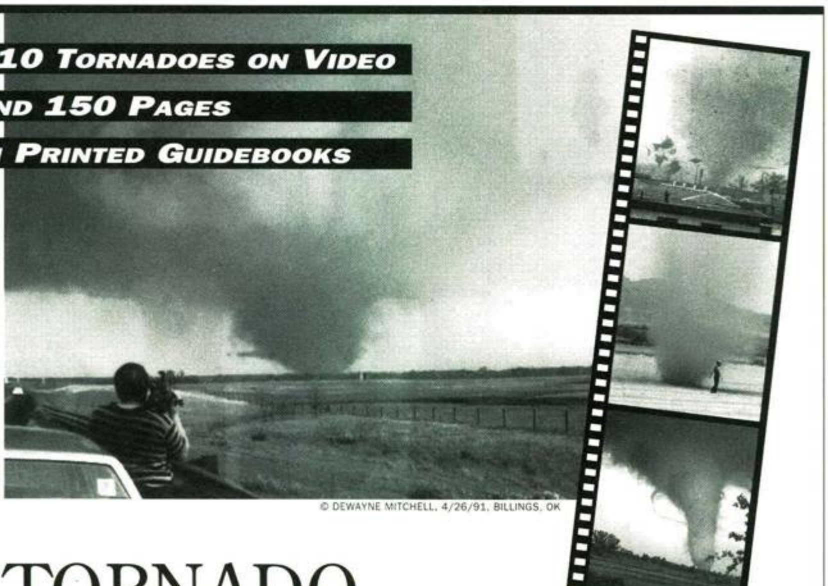

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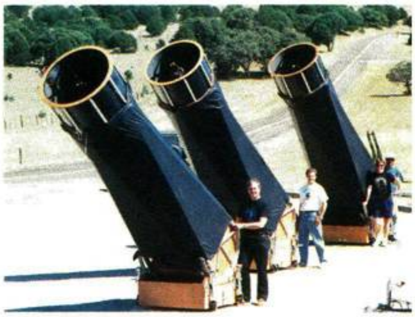
ladders and looked at the cosmos. "We're like cosmic Johnny Appleseeds sowing generations of astronomers to come," Sheryl says, her voice wafting over the gentle chords of New Age music.

The music, the large-aperture scopes, (the billberry pills?) have conspired to make my head swim. Time to wander the firmament and discover wonders by serendipity. I retreat to my monster binocs. In one corner of the field, I use them to grasp and glean $3^{1/2}$-degree chunks of the sky. Extremely faint and subtle IC 342, a face-on galaxy in Camelopardalis, fills the whole field of view. Wisps of bluish nebulosity splash from the stars of the Pleiades. The great spiral galaxy M31 in Andromeda, sporting obvious dust lanes, sprawls across five degrees of sky. I hear myself filling the desert air with ooohs and aaahs. Distant coyotes answer in parody.



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There's a tap on my shoulder — it's Bob Ross down from his ladder to see what all the commotion's about. I oblige him by dialing in object after object that knocked at least a layer of socks off my feet. Soon Bob has binoc fever. Never in a million years, he says, would he have expected to see stuff so faint and in such detail through — gulp — binoculars. A born-again binocular man? Perhaps not, for there are many wonders awaiting him through an eyepiece in the business end of a 36-inch. He goes back to his ladder, and for a moment I set aside the binocs to just look at the sky.

The big scopes silhouetted against knots of dark and light along the Milky Way say it all. They go deep, I go wide, real wide. The gentle murmur of voices, a warm, silky breeze on my face.

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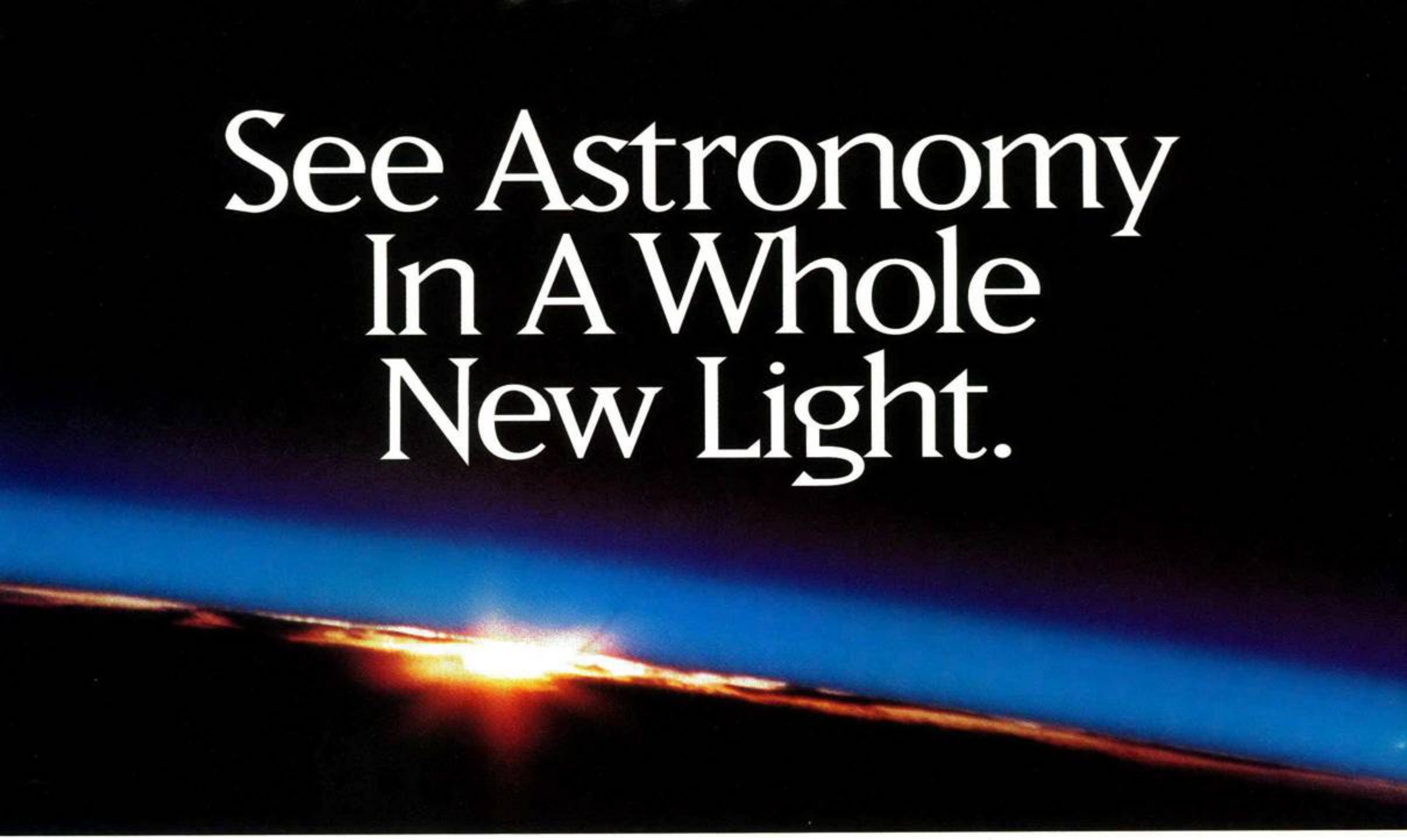

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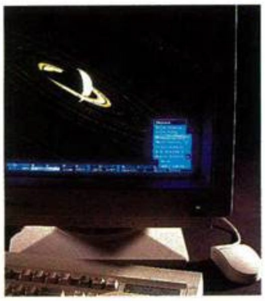

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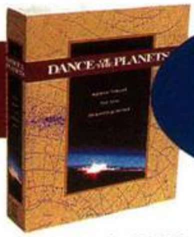

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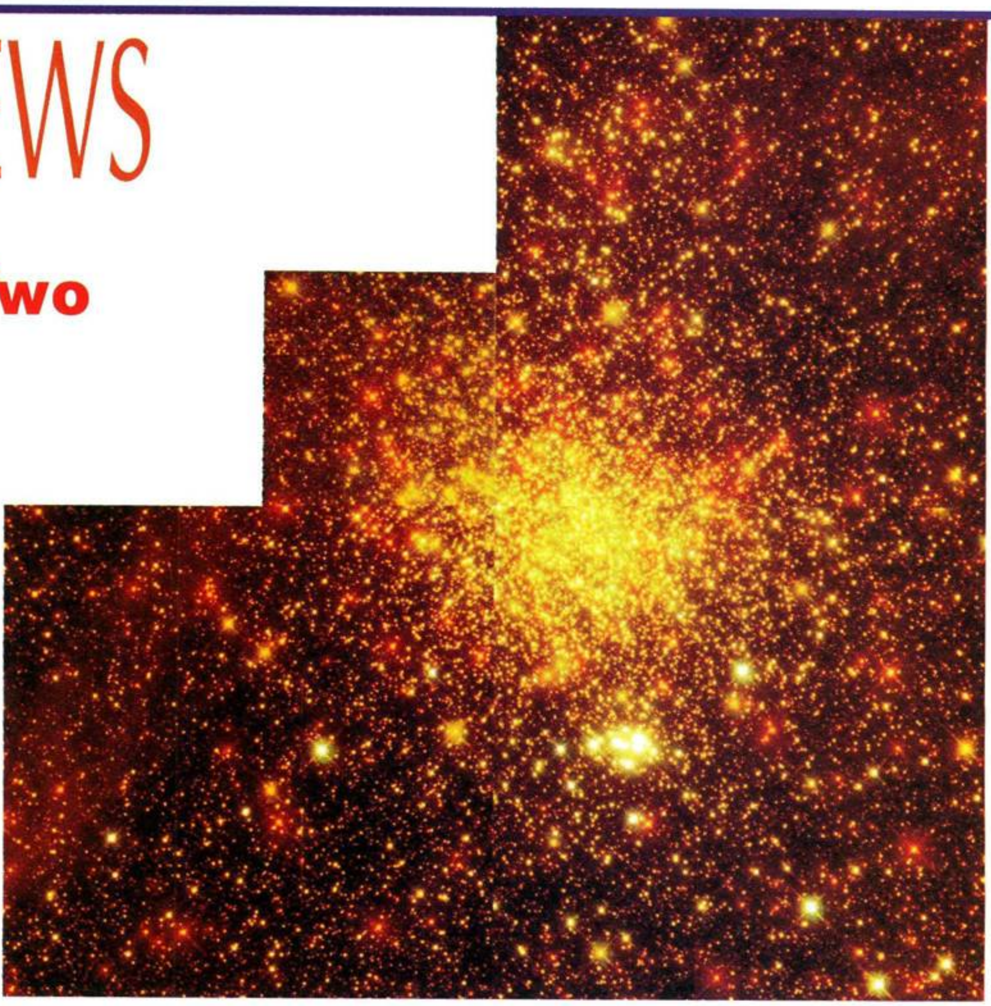
# A Tale of Two Clusters

New insights into how stars might have formed early in the universe were revealed last October by scientists using the Hubble Space Telescope. The results were published in the November 1, 1994 issue of the *Astrophysical Journal.*

Nino Panagia of the Space Telescope Science Institute and his collaborators studied the open star cluster NGC 1850 in the Large Magellanic Cloud and found that its yellow stars are about 50 million years old. Curiously, however, the astronomers found a scattering of young white stars throughout the field. These suns are only 4 million years old and separated from the cluster by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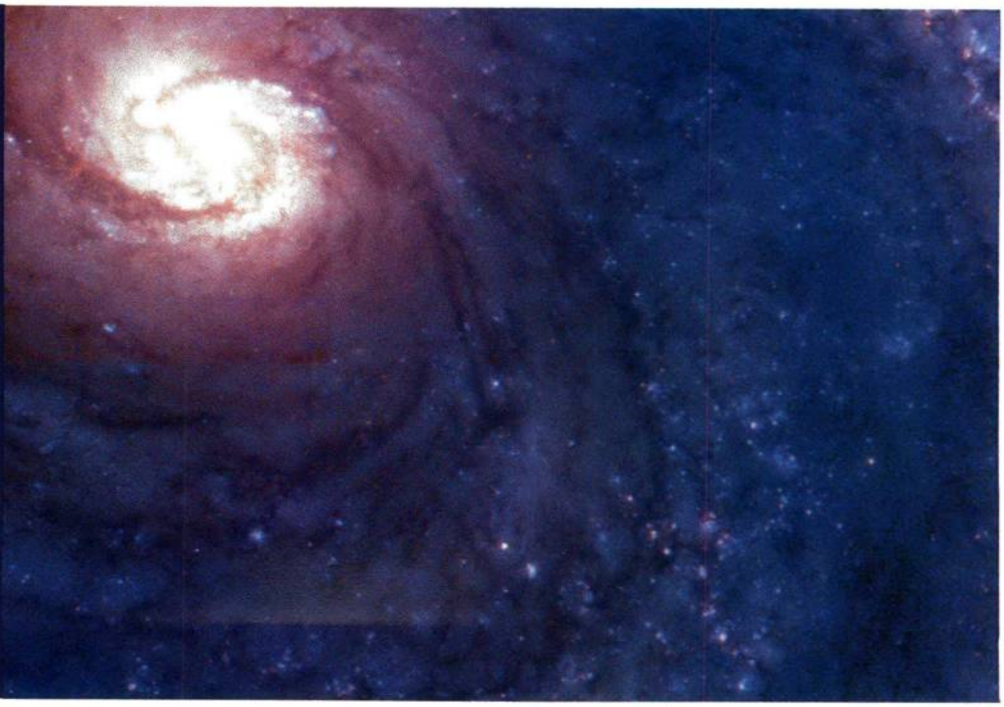
**THE RICH CLUSTER NGC 1850** appears as a tight clump of yellow stars in this Hubble Space Telescope image. The scattering of bright white stars across the image represents another, younger cluster that may have formed when supernovae in the older cluster exploded.

**HUBBLE NARROWS AGE OF THE UNIVERSE:** On the heels of a ground-based measurement of a spiral galaxy in the Virgo Cluster (see AstroNews, January 1994), astronomers using the Space Telescope determined that M100 (right) lies 56 ± 6 million light-years away.

The finding agrees well with the measurement to NGC 4571, another Virgo galaxy, both pinpointed by measuring the brightnesses of Cepheid variable stars. This suggests the age of the universe is a mere 8 to 12 billion years, a number that is uncomfortably small to some astronomers: Measurements of the ages of stars in our Galaxy imply they are 14 to 16 billion years old.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only about 200 light-years.

The astronomers suggest the young cluster formed from the shocked bubble thrown off by supernovae in the older cluster. The process would have been an important way to make stars in the early universe, so the astronomers will search for more such pairings.

## Hubble Views Distant Galaxy Cluster

**H**ubble Space Telescope observations of galaxies in the cluster Cl 0016+16 show that many of this cluster's active galaxies have unusual shapes, implying they have interacted. The study also suggests that different processes may be at work in different clusters to produce a certain variety of active galaxy.

Gregory Wirth and David Koo of Lick Observatory and the University of California, Santa Cruz, and Richard Kron of the Fermi National Accelerator Laboratory in Batavia, Illinois, chose Cl 0016+16 in part because of its richness and relatively high redshift (z=0.55), which indicates a great distance. The cluster also ranks among the brightest X-ray clusters and has many active galaxies. Previous observations had produced surprising results: Although virtually all of Cl 0016+16's galaxies appear red, normally a sign of old galaxies that no longer produce many stars, spectra showed lots of recent star formation.

Using high-resolution images taken with Hubble's Wide-Field Camera, the researchers found that most of the normal, non-active galaxies expected to be elliptical or lenticular galaxies containing mostly old stars indeed appeared round and smooth. On the other hand, most of the galaxies having emission lines or strong hydrogen absorption in their spectra (a sign of ongoing star formation) appeared disklike and possessed double nuclei, tidal tails, or companion objects lying closer than 2".

Perhaps most interesting, the researchers found that the galaxies having strong hydrogen absorption resembled galaxies previously studied in the cluster Cl 0939+47. But they differed markedly from those seen in AC114, over half of which looked normal. The authors conclude that since these active galaxies have different forms in different clusters, they may have diverse origins. They report their results in a Letter scheduled to appear in the *Astrophysical Journal*.

## Comets: Breakin' Up Is Easy to Do

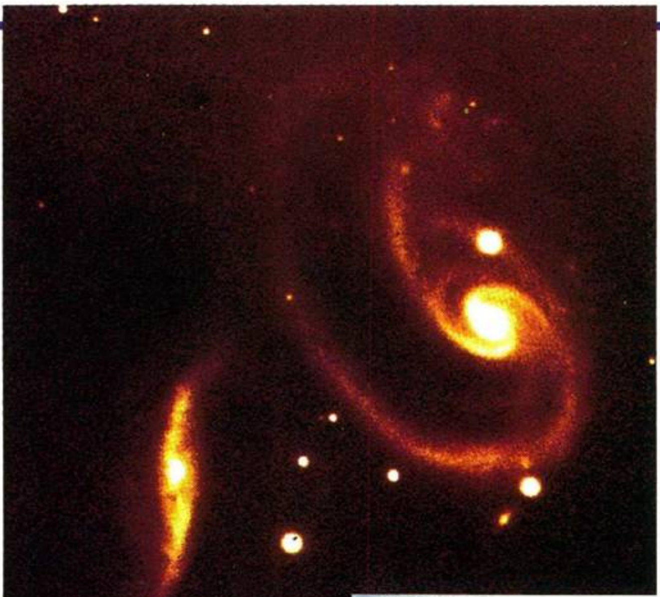
**F**ind one and suddenly they're everywhere. With the example of Comet Shoemaker-Levy 9 still fresh in everyone's mind, planetary astronomers are finding split-up comets every time they turn around, it seems. Recently (see AstroNews, December 1993) it was Comet Machholz 2 (1994o); now it's Comet Harrington (1994g).

James Scotti of the University of Arizona's Spacewatch team found that Comet Harrington's main nucleus has two faint companion nuclei. When the companions were discovered on October 4, they were 9" apart and lay some 23' away from the main nucleus in position angle 245°. Fragments A (the largest) and C also had tails 10' and 1' long. The three nuclei had magnitudes of 12.8, 21.3, and 20.2, respectively.

By mid-October a number of backyard astronomers had imaged the comet.

Why all the broken comets in the news lately? In a report published in the April 1994 issue of *Icarus*, Jun Chen and David Jewitt of the University of Hawaii say it's just what we should expect. Chen and Jewitt conclude, after studying how often periodic comets break apart and spawn subnuclei, that on average every comet has a one percent or greater chance of breaking up in any given year. The splitting may be caused, for example, by tidal encounters with a planet or the Sun, a large meteorite strike, a massive outburst on its surface, or some other energetic event.

"Although perceived as rare by observers," they say, "splitting is a common occurrence in comets."



University of Wisconsin

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## First Light for WIYN Telescope

**T**he faint, interacting galaxies of Arp 273 in Andromeda (above) show remarkable detail in this first-light image from the 3.5-meter WIYN telescope on Kitt Peak, Arizona (above, right). The telescope, which will undergo testing until sometime this spring, is a joint venture of the University of Wisconsin, Indiana University, Yale University, and the National Optical Astronomy Observatories. The telescope's spun-cast mirror, open-architecture dome, and computer-controlled actuators in the mirror cell are producing images that "surpass our highest hopes," says Blair Savage of the University of Wisconsin.

The telescope's time will be shared between the four institutions. The telescope itself will be controlled remotely, allowing graduate students and even undergraduates to access a major ground-based observatory. "This is an extremely uplifting opportunity," says Todd Tripp, a Wisconsin graduate student who will use the telescope to compare the ancient universe with the modern universe by looking at relatively nearby quasars and extremely distant ones.

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***M51 Whirlpool Galaxy:*** *The first galaxy found to have spiral structure is about 35 million light years distance and about 10 arcmin in apparent diameter. The entire spiral pattern is dominated by narrow dust lanes which can be traced deep into the nuclear region. The satellite galaxy evidently does not lie exactly in the plane of the big spiral, since dust lanes of the M51 arm can be seen crossing in front of it. Twenty minute Model ST-7 CCD image taken through an Astrophysics EDF, f/7 refractor through hazy skies. Post processed with TheSky astronomy software by Software Bisque. Courtesy Tony Hallas, Oakview, California.*

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## Probing the Big Bang

**A**ntoinette Songaila of the University of Hawaii and her colleagues have provided two tests of big bang cosmology — and the big bang passes in both cases. Using the 10-meter Keck telescope on Mauna Kea in Hawaii, the astronomers measured both the amount of deuterium (heavy hydrogen) in what is presumably a primordial gas cloud and the temperature of the cosmic background radiation.

The gas cloud lies about 11.8 billion light-years away and contains less than one deuterium atom for every 4,000 normal hydrogen atoms. That implies that the matter visible in galaxies accounts for all normal matter.

The missing or dark matter of galaxies can't be normal atoms such as those making up planets and low-mass stars — but must be exotic particles not yet detected by scientists. The only potential problem with this discovery is that a nearby moving cloud of normal hydrogen may have contaminated the observations. Future Keck observations will determine whether this is the case.

The temperature of the background radiation according to big bang models should cool with increasing distance. Songaila and her team looked at how the background radiation filled in a dark absorption line of carbon in the spectrum of a quasar lying 11.4 billion light-years from us.

At this distance, the background radiation should have a temperature of 10.66 K according to model predictions. The filling in of the line sets an upper limit of 13.5 K on the temperature. Additional observations may rule out other explanations promoted by alternative cosmological models.

## New Theory for Gamma-Ray Bursts

**B**ursts of gamma rays could originate in a complex chain of events that starts when a star's entire mass gets converted to a juggernaut of kinetic energy expanding at nearly the speed of light. The nature of these enigmatic gamma-ray bursts has puzzled astronomers since they were discovered more than twenty years ago.

The theory, advanced by Martin Rees of Cambridge University and Peter Mészáros of Penn State University advanced this theory in the August 1, 1994 *Astrophysical Journal Letters.* Their theory seems to explain an unusual burst observed by the Compton Gamma Ray Observatory on February 17, 1994, better than any of the 100-plus theories that preceded it. The remarkable burst (see AstroNews, November 1994) lasted over an hour and consisted of gamma rays 12 times more energetic than any seen in previous bursts. Its beginning, however, coincided with a shorter, lower-energy burst. According to the new theory, these were two different bursts caused by the same initial event.

Rees and Mészáros propose that the burst begins in a cataclysmic event that ejects debris at high speed. The event could be the collision of two neutron stars, the swallowing of a neutron star by a black hole, or the explosion of a collapsed star known as a failed supernova.

As the pieces of debris race away at various speeds, fast-moving material ejected later in the explosion catches up with and smashes into slower moving material ejected earlier. This collision *produces a short burst of* relatively low-energy gamma rays.

## AMATEUR NEWS

## On Top of Old Smoky

**L**ast August, western Canada's largest star party was almost smoked out. Held each year on the summit of a 6,000-foot mountain near Osoyoos, British Columbia, the Mt. Kobau Star Party draws amateurs from all over the Pacific Northwest, attracted by the super-dark skies. But in 1994, record forest fires only valleys away in southern B.C. and northern Washington and Idaho blanketed much of northwestern North America with murky haze.

In fact, if the star party had been held a week earlier, everyone might have had to evacuate the summit as one fire close to tinder-dry Mt. Kobau threatened to cut off the only road to safety. But welcome rains just before the official start of the Star Party on August 10 cleared the air, providing 220 participants with four nights of some of the finest skies Mt. Kobau has ever offered. The deep-sky views were memorable.

The near-record attendance was due to the timing of the star party with the Perseid meteor shower. Partygoers anticipated a spectacular display, as the shower was expected to peak over western North America on the night of August 11/12. During the initial hours of the Perseid watch, things were disappointingly slow. But in the predawn hours activity accelerated, perking up tired observers with rates of up to 120 meteors per hour for one observer. The Perseids came through after all!

Next year, the Mt. Kobau Star Party is set for August 23 to 27. For more information, contact Peter Kuzel, 4100-25th Avenue, Vernon, B.C., Canada V1T 1P4.
— *Alan Dyer*

Alan Dyer

**TENTS, TELESCOPES, AND TIRED OBSERVERS** covered the summit of Mt. Kobau in western Canada last August. Braving threats of forest fires, 220 amateurs were rewarded with nature's fireworks display — the Perseids at peak.

The debris continues expanding, however, until it hits the interstellar matter surrounding the original colliding or collapsing stars. This second collision generates the long-lived, higher energy burst. The theory also predicts correctly the spectrum of the gamma-ray burst. If Rees and Mészáros' theory is true, low levels of X rays and visible light should be produced along with the gamma rays. Looking for those emissions will be one of the goals of NASA's High-Energy Transient Experiment scheduled for launch early this year.

## Setting a Limit on Stars

The haloes of galaxies contain lots of dark matter, but astronomers still don't know what it is. They have recently detected microlensing of light from distant stars and believe it is caused by objects in the Milky Way's halo. (Microlensing, the gravitational focusing of light by a large planet or a star, occurs when an unseen body lies between Earth and the background star; see "A Brightening Star Reveals Dark Matter," August 1994.)

The objects in this case, the astronomers suggest, might be very-low-mass stars (those with about 10 percent the mass of the Sun) making up dark matter. And these very-low-mass stars should be observable in the infrared, if they exist.

The team, led by Esther Hu of the University of Hawaii in Honolulu, used the 2.2-meter University of Hawaii telescope on Mauna Kea to look for the infared emission in four regions of sky, each 3' by 10' long. They measured the brightness of each object in the regions

# Space Flight News Notes

## Space Station Schedule Revised

HOUSTON — During a meeting held in late October 1994, NASA managers released a revised assembly schedule for international space station Alpha. The first assembly flight will occur in November 1997, followed by the launch of a U.S. laboratory module in November 1998, the Canadian robot arm in December 1998, Japan's experiment module in March 2000, and a European module in February 2001. Russia's main contribution to the station, a solar power platform, will be launched between late-1998 and mid-1999. The station should be completed by June 2002.

FLIGHT HARDWARE
DO NOT
TOUCH

Boeing Defense & Space Group

**THE SPACE STATION TAKES SHAPE** in Huntsville, Alabama, where technicians stand in a node that will connect sections of the station. This piece will be launched in December 1997 and join up to four modules for experiments.

## Galileo Suffers Memory Loss

PASADENA — Jupiter-bound Galileo suffered the loss of a memory cell on September 13, 1994. This forced the spacecraft into a dormant "safe" state for 12 days until controllers traced the problem and reprogrammed Galileo's computer around the faulty cell. At the time, the craft was transmitting data on Comet Shoemaker-Levy 9's impact with Jupiter at a rate of 10 bits per second. Transmission of the comet crash data concluded in January. Galileo enters Jovian orbit this December.

## Explorer To Study Starburst Galaxies

PASADENA — A small satellite launched from a modified DC 10 airplane in October 1998 will study galaxies undergoing tremendous bursts of star formation. The Wide Field Infrared Explorer (WIRE) carries a cryogenically cooled, 12-inch telescope developed by Utah State University to observe starburst galaxies 500 times fainter than those surveyed by the Infrared Astronomical Satellite in 1983. During WIRE's four-month lifetime in low-Earth orbit, it will also catalog fainter starburst galaxies missed by IRAS.

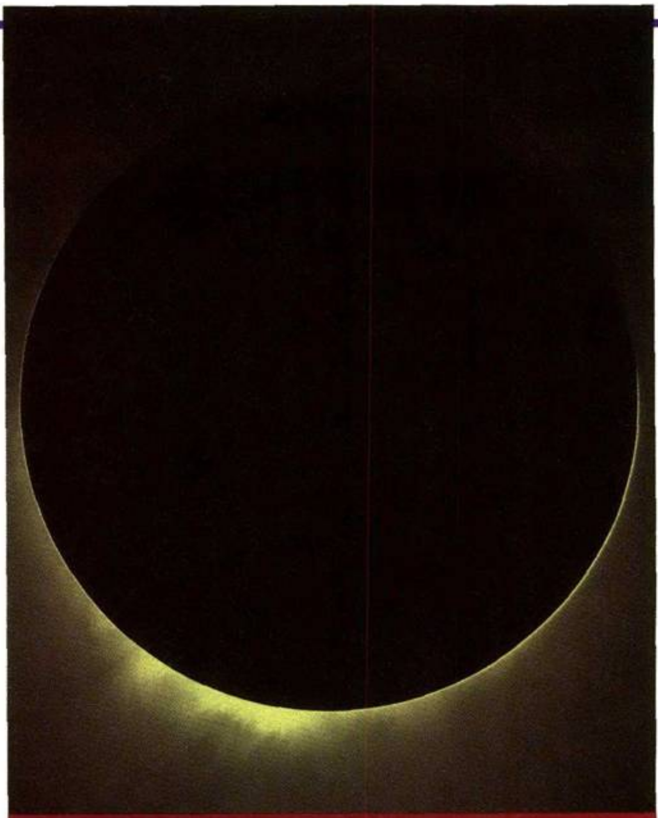
## NEAR Team Selected

WASHINGTON — In October 1994 NASA selected science team leaders for the Near Earth Asteroid Rendezvous spacecraft, scheduled for launch in February 1996. Joseph Veverka of Cornell University will head the multispectral imager/near infrared spectrograph team; Jacob Trombka of NASA's Goddard Spaceflight Center (GSFC), the X-ray/gamma-ray spectrometer; Mario Acuna of GSFC, the magnetometer; Maria Zuber of GSFC, the light imaging detector and ranger; and Donald Yeomans of JPL, radio science. NEAR reaches 433 Eros in January 1999, where it will orbit and study the asteroid for one year, approaching as close as 15 miles.

in three colors so they could determine its probable mass and luminosity.

The study, however, does not show this infrared emission, so the team has concluded that the dark matter, if it is normal matter and not exotic high-energy particles, must consist of non-stellar objects such as massive planets or brown dwarfs, failed stars that have not accrued enough mass to "turn on" like stars.

The team predicts that future searches for microlensing events will detect mostly brown dwarfs that have masses less than 7 percent the mass of the Sun. Events caused by more massive objects, the tiniest stars, should be rare because objects of this size are less common. Their findings were reported in the October 6, 1994 issue of *Nature.*



National Solar Observatory/NOAO

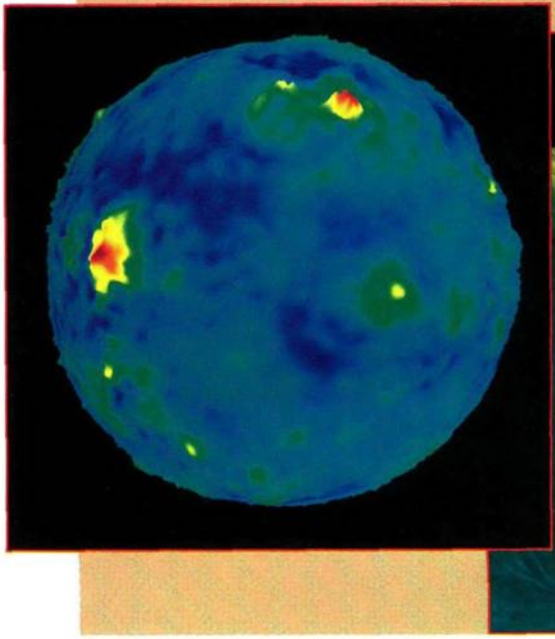
**THE MAY 1994 ANNULAR ECLIPSE** wasn't just a great show: It yielded information about how coronal temperatures vary with height. Astronomers led by Bernard Jackson of the University of California at San Diego and Richard Altrock of the Air Force Phillips Lab used a coronagraph at the National Solar Observatory to block the light of the Sun's disk and view the faint loop systems in the corona during the eclipse. Appearing at right against the background corona, the Moon's limb helped establish the height of individual features. The Moon isn't as dark as the black disk hiding the Sun's disk because of earthshine and light scattered in the sky.

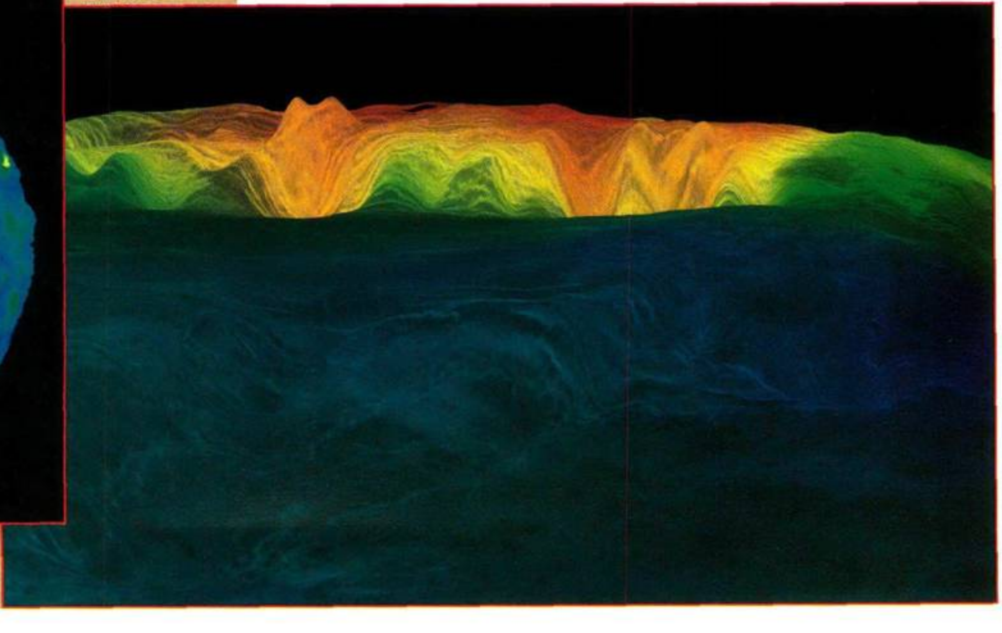
## Magellan's Fiery End

During the week of October 10, 1994, the Magellan spacecraft received groundbased commands to commit suicide. The highly successful but ailing spacecraft, which completed all of its major mission goals, plummeted through the Venusian atmosphere, its solar panels shearing off, antenna collapsing, and finally its two major pieces striking Maxwell Montes, the largest mountain on the planet.

The fiery end came after Magellan's last data gathering, which included a gravity map of Ishtar Terra and Maxwell Montes (below, right), showing high gravity anomalies in red and low gravity anomalies in blue. This suggests the reddish highlands are being supported by energy deep inside the planet's mantle while the bluish lowlands are "floating" in the planet's thick crust. The spacecraft also produced a global gravity map (below) using the same color scheme: Maxwell Montes appears near top right, Beta Regio at left center, and Gula Mons at right center.

NASA/JPL





# CELESTRON®

GP-C102-ED

**GP-C102 TELESCOPES** — The Celestron line of 102mm German equatorial mount refracting telescopes is for the more serious astronomer who appreciates exquisite optics and stable mounts.

The Great Polaris (GP) German equatorial mount is the new, upgraded evolution of the Super Polaris (SP) mount.

The fine Japanese optics include a superb achromat (1000mm fl) in the standard GP-102. The GP-C102-ED is a super premium refractor utilizing super ED glass which rivals the best color correction, resolution and contrast of any refractor in its class — it is 900mm fl.

1.25" Eyepiece Filters

**EYEPIECE FILTERS** — These filters are an invaluable aid to lunar and planetary observers. They reduce glare and light scattering, increase contrast by selective filtration, increase definition and resolution, reduce irradiation and lessen eye fatigue.

Celestron offers the most complete line of eyepiece filters in the industry but more importantly — the finest quality filters. Celestron filters offer 18mm clear aperture for the .96" size, a full 26mm clear aperture in the 1.25" size and 44mm clear aperture in the **2" size**. The filters utilize quality, solid plane parallel glass with excellent homogeneity. The filters are anti-reflection coated on **both sides** of the glass to prevent glare and ghosting.

The filters are mounted in black anodized aluminum cells with the Kodak Wratten Series engraved on each one and they are supplied in a plastic case.

Coma Corrector

**COMA CORRECTOR** — This multi-purpose Coma Corrector virtually eliminates coma and astigmatism in Newtonian telescopes without increasing the focal ratio of your telescope. Its unique lens design utilizes a multi-coating on all air-to-glass surfaces to allow 97% transmission (with maximum transmission in the hydrogen-alpha region of the spectrum). Although optimized for f/4.5 mirrors, it works well with mirrors from f/4 to f/6. Stars remain 12 micron dots over the entire field.

It can be used BOTH visually and photographically. Fits virtually all 1.25" and 2" focusers and off-axis guiders with the adapters supplied. New version allows the visual use of 2" oculars.

LV Eyepieces

**LV EYEPIECES** — A new generation of eyepieces using the rare earth glass — lanthanum. **All** focal lengths have a **20mm eye relief!** Optics are all **fully multi-coated.** The results are excellent and high power viewing is more relaxed.

| FOCAL LENGTH | BARREL DIA. | APPARENT FIELD |
|---|---|---|
| 2.5mm | 1¼" | 45° |
| 4mm | 1¼" | 45° |
| 5mm | 1¼" | 45° |
| 6mm | 1¼" | 45° |
| 9mm | 1¼" | 50° |
| 10mm | 1¼" | 50° |
| 15mm | 1¼" | 50° |
| 20mm | 1¼" | 50° |
| 25mm | 1¼" | 50° |
| 30mm | 2" | 50° |

2" Star Diagonal

**DIAGONAL – 2"** — A standard 2" Mirror Star Diagonal. It is an improved version of the unit previously offered and it includes an adapter to accept 1.25" eyepieces. It has **multi-coated** optics and the mechanics are smooth and precision manufactured.

**REDUCER/CORRECTOR f/6.3** — This combination focal reducer and field corrector lens accessory works with all Celestron C5's, C8's, C11's and C14's. Now it is possible to have a dual focal ratio instrument without sacrificing image quality. The Reducer/Corrector is f/6.3 for C5, C8 and C11, f/7 for C14. The drawbacks of a dedicated f/6.3 Schmidt-Cassegrain with its much larger central obstruction (causing reduction of contrast) and the inability to utilize longer focal ratios for certain objects led us to design this four element, **fully multi-coated** accessory. Results are amazing BOTH visually and photographically. ***Far superior to competitive units!***

Reducer/Corrector f/6.3

**RADIAL GUIDER** — Specifically for use in prime focus, deep sky astrophotography, the Radial Guider is compact and sleek in design. It allows you to simultaneously photograph and guide through the optical tube assembly of your telescope. With the Radial Guider, the problem of differential flexure is eliminated as you are both guiding and photographing through the telescope. It includes: "T"-shaped body, prism adjustment screw, eyepiece holder and screws.

This guider is a tremendous improvement over conventional off-axis guiders. **The angle of the prism is tunable.** It has a fixed rigid camera orientation while the user is free to move the guiding eyepiece radially about 135°!

Radial Guider

MFFT-55

**MFFT-55** — Celestron's Multi-Function Focal Tester-55 (MFFT-55) is a focusing aid designed to allow astrophotographers to accurately evaluate their telescope's focal plane in three main areas of interest: focus, collimation (squareness), and curvature of field. With the MFFT-55, you can focus on and off the optical axis at 3, 16, 22 and 30mm diameters in four quadrants in a single setup.

The MFFT has a black anodized tube and a glass plate with opaque and reflective coatings etched into a three zone reticle pattern. The glass plate is positioned at 55mm — the exact distance from the front face of the T-ring to an SLR film plane. It screws onto the Radial Guider to achieve "perfect" focus.

**FLASHLIGHT** — A flashlight with a **red LED** for star map reading and night use at the telescope. The LED does not impair night vision. Also great for bird watchers to study field guides in low light conditions without disturbing the birds. Compact at only 6" long and weighs just 2.5 oz. Two AA batteries are included.

Flashlight, LED

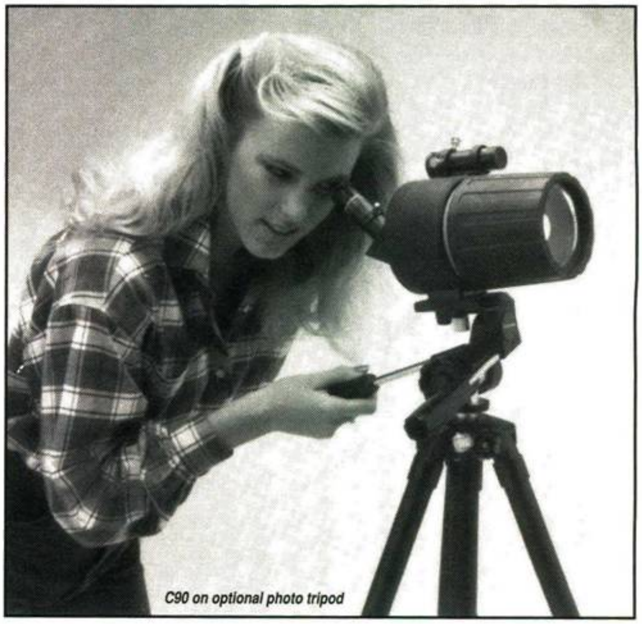
Accessory Case

**ACCESSORY CASE** — Protect your investment in quality optics and accessories with a rugged carrying case. Celestron's Accessory Case is constructed of durable ABS plastic. The inside has foam padding, die cut in small squares allowing you to custom fit your accessories. Size 13" x 10" x 5.75".

**C90 SPOTTING SCOPES** — Over the years, the C90 has proven to be the most popular Celestron spotting scope. Used by tens of thousands of satisfied customers worldwide. Clearly the world's leader in this size spotting scope.

Superb optics — a full 90mm (3.55") aperture f/11 Maksutov-Cassegrain mirror lens optical system. At only 3' pounds and 7¾" in length, the C90 is light and compact enough to travel with you anywhere.

Several models are available — some with rubber coverings, some with 1¼" accessories and most with multi-coating. **Made in the USA!**


C90 on optional photo tripod

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**Meade & Celestron**
LUMICON Carries a full line of telescopes & accessories. Fast Delivery, competitive prices

# LUMICON FOR HIGH PERFORMANCE

UMICON H-B
MICON OIII
MICON UHC
ON DEEP-SKY

**FILTER OF THE MONTH:** LUMICON **H-Beta Filter** will help you see the Horsehead Nebula from a dark site and 10" or larger telescope.

## "I'd Pick The TELE VUE™"

*40mm Wide-Field Test, "Astronomy," Aug. 1990, p. 90*

| | |
|---|---|
| **Genesis 4" f/5 4 element fluorite** | $1885 |
| Pronto 70mm f/6.4 apochromat w/2" diagonal | $825 |
| Pronto 70mm f/6.4 w/45° erecting prism | $725 |
| **Renaissance-SDF** 4" f/5.4, brass | $2095 |
| Gibraltar mount with ash wood tripod | $495 |
| **7.4, 10.4, 13, 17, 21, 26mm Plossl** 50° | $79 |
| **1.8x or 2.5x Tele Vue Barlow Lens** | $89 |
| **2" Giant Barlow - 2x** | $169 |
| **32mm Plossl**, widest true field in 1¼" | $109 |
| **55mm 2" Plossl**, widest possible field | $219 |
| **15mm Wide-Field**, 1¼" eyepiece, 65° | $135 |
| **19mm Wide-Field**, 1¼" eyepiece, 65° | $145 |
| **32mm Wide-Field**, 2" eyepiece, 65° | $239 |
| **40mm Wide-Field**, "Rich-Field!" 65° | $299 |
| **4.8mm Nagler**, 82° field, 1¼" eyepiece | $149 |
| **7mm Nagler**, 1¼" eyepiece, 82° field | $189 |
| **9mm Nagler**, 82° field, 1¼" or 2" | $219 |
| **13mm Nagler**, 82° field, 1¼" or 2" | $249 |
| **12mm Nagler**, Type II, 82°, 1¼"/2" | $249 |
| **16mm Nagler**, Type II, 82°, 1¼"/2" | $289 |
| **20mm Nagler**, Type II, 82°, 2" only | $340 |
| **1¼" Paracorr Visual Coma Corrector** | $159 |
| **2" Paracorr Visual Coma Corrector** | $249 |
| **NEW! 15mm Panoptic 1¼"**, 68° field | $199 |
| **NEW! 22mm Panoptic 1¼"/2"**, 68° | $249 |
| **NEW! 27mm Panoptic 2"**, 68° field | $299 |
| **NEW! 35mm Panoptic 2"**, 68° field | $325 |

## ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.

**LUMICON Adjust. Piggyback Mount $59.50**
Specify telescope size: 6", 8", 10", 11", 14", 16"

## H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

| **Specify Lens Size** | **H-Alpha** | **(MV)** |
|---|---|---|
| 46, 48, 49mm | $59.00 | $49.00 |
| 52, 55, 58, 62mm | $69.00 | $59.00 |
| 67, 72, 77mm | $79.00 | $69.00 |
| 82mm | $89.00 | N/A |

Hypered 2415 film, 36 exp ... $11.95, $3/$32

## NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

**LUMICON 1.3" & 2.1" enhanced aluminum diagonal mirrors & 1¼" star diagonal.**

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding up to an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

| | | | | | |
|---|---|---|---|---|---|
| 1.32" | **$39.50** | 1.52" | **$45.00** | 1.83" | **$49.50** |
| 2.14" | **$59.50** | 2.60" | **$75.00** | 3.10" | **$99.50** |

## ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

| | |
|---|---|
| 1¼" (1.32" mirror) | $99.50 |
| 2" (1.83" mirror)(see photo above) | $169.50 |

## LUMICON FILTERS — BEST IN THE WORLD!

***"The LUMICON OIII proved to be our favorite... It gave the greatest contrast gain."***
***ASTRONOMY February 1991***

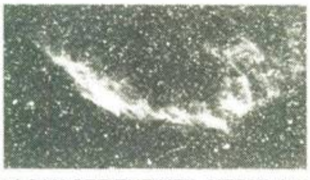
### AMAZING OIII FILTER™

**Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.**

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90-96% for both O-III lines at 496nm and 501nm.

### SEE THE HORSEHEAD!

**Horsehead Nebula in Orion.** This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.



### "I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*

**Rich Zepernick, Cresskill, NJ**

### DEEP-SKY FILTER™

### BEST for Astrophotography!

*"Stunning is all I can say,"* says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

### BEST WIDE-BAND FILTER!

*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for* ***reflection*** *nebulae."*

***Astronomy, Feb. 1991***

| | Premium* |
|---|---|
| **0.96" LUMICON DEEP-SKY Filter** threads into most 0.96" eyepieces | $59.50 |
| **1¼" LUMICON DEEP-SKY Filter** threads into most 1¼" eyepieces | $79.50 |
| **48mm LUMICON DEEP-SKY Filter** (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS | $119.50 |
| **2" LUMICON DEEP-SKY Filter** (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography | $119.50 |
| **72mm LUMICON Giant DEEP-SKY Filter** (62, 67, 77mm adapter, $8) | $299.50 |
| **2" Rear Cell Filter,** fits SCT's ... Deep-Sky, **$119.50** UHC, O-III, H-Beta, | $199.50 |
| **1¼" LUMICON UHC Filter** threads into most 1¼" eyepieces | $99.50 |
| **48mm LUMICON UHC Filter** (1.75" aperture) fits most 2" eyepieces | $199.50 |
| **DEEP-SKY** and choice of **UHC, O-III or H-BETA** Filter (Save 11%) 1¼" **$159.50**; 48mm | $279.50 |
| **LUMICON H-BETA Line Filter** (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** ... **$99.50, 48mm** | $199.50 |
| **Oxygen-III Filter** for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines ... **1¼" $99.50, 48mm** | $199.50 |
| Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm | $6.95 |
| Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece | $16.00 |
| Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece | $25.00 |

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

# DEEP-SKY ASTROPHOTOGRAPHY

## SR-V 3200 NEW FILM

### FILM HYPERSENSITIZATION KITS†

**LUMICON HYPER-KITS™** yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†U.S. Patent 4,473,636

### MAKE YOUR OWN HYPERED FILM

**MODEL 300 HYPER-KIT** sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds ... **$325**

**MODEL 600 HYPER-KIT** (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates ... **$395**

**MODEL 1200 HYPER-KIT** is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller ... **$595**

Temperature controller for any HYPER-KIT ... **$75**

Electric Vacuum Pump, Model R-10 **$325**

### GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars. †U.S. Patent 4,448,500
*Specify Camera and Telescope type.*

### NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

| | |
|---|---|
| NEWTONIAN EASY-GUIDER | **$189.50** |
| 48mm Coma corrector/field flattener | **$285** |
| 3X Relay Diagonal (see photo) | **$99.50** |
| Illuminated reticle eyepiece, pulsed | **$109.50** |

Guider for Hasselblad **$409,** Mamiya 645 **$199**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

### CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER ... **$249.00**
Adapter for Hasselblad **$225,** Mamiya 645 **$98**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

### GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER ... **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) ... **add $99.95**
Adapter for Hasselblad **$295,** Mamiya 645**$149**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

### WHAT DO YOU NEED?

1. Illuminated reticle eyepiece ... **$99.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.

2. Cable release for long exposures ... **$9.95**

3. **LUMICON Digital Drive Corrector** . **$249**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 30Hz/90Hz variable output controls telescope drive. 60Hz digital reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Dec. reverse switch for Newtonians.

**Declination motor** (state telescope) ... **$109**
Variable dec. speed drive w/built-in 5AH battery **$299**

### HYPERSENSITIZED FILM

SR1600
Scotch
1000

NEW SRV3200

***YES! WE STILL HAVE FUJI HG400!***

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

| **Film Type, 35mm** | **Exposures** | **Price** |
|---|---|---|
| 2415, Ultra-fine B&W, red sens. | 36 | $11.95 |
| SR-G3200, fastest of all, color neg | 24 | $14.95 |
| Kodak Ektar 1000 fast, fine grain | 24 | $12.95 |
| **Fuji HG400** fine grain color neg. | **24** | **$14.95** |
| Scotchrome 400, fast slide film | 12 | $12.95 |
| Fujichrome RD100, fine grain slide | 24 | $12.95 |
| D-19 B&W Developer | 1 gal. | $6.95 |

# LUMICON®

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**FAX (6 PM-9 AM PST) (510) 447-9589**
**LUMICON Products catalogue FREE**
**All foreign orders add 8% ($10 minimum)**
**California residents add 8.25% tax.**
**Prices subject to change w/o notice.**
**Hrs: M-F 9 am - 5 pm, Sat. 11 am - 3 pm**

# LUMICON® ACCESSORIES | MEADE® TELESCOPES

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## LED FLASHLIGHT . $14.95

**LUMICON LUMILITE™ Red LED Flashlight**

This red LED flashlight preserves night vision. It uses 2 AA cells (included!) which last 60-100 hours.

| | |
|---|---|
| **LUMILITE** red LED flashlight ..... | **$14.95** |

## DRIVE CORRECTORS

**LUMICON UNITRAK DRIVE CORRECTOR**

Operate your telescopes ***anywhere!*** Use the single-axis Unitrak with a 12V DC car battery. The dual-axis drives are for photography and use either 12V DC or 125V AC.

| | |
|---|---|
| Unitrak™ single-axis corrector ..... | **$99.95** |
| LUMICON DX200 dual-axis correc. | **$249.00** |
| DX2BP incl. battery & charger ... | **$298.00** |

Convenient rechargeable Porta-Pac battery:

| | |
|---|---|
| 12V DC Porta-Pac (5AH) & recharger | **$79.50** |
| 12V DC Porta-Pac (12AH) & refharger | **$99.50** |

## 48MM COLORED FILTERS

### FOR EVERY NEED

| | |
|---|---|
| Select 48mm UV, Red, Yellow, Green (ea.) | **$20.00** |
| 48mm Cyan (absorbs red) .......... | **$69.00** |
| 48mm High Performance Blue (95% T) | **$49.00** |
| 48mm Tri-Color Blue (80% T- 400nm) . | **$49.00** |
| 48mm Ultraviolet (85% T- 370nm) .... | **$49.00** |
| Color Separation Set: cyan, red, yellow, blue | **$149** |

## RICH FIELD! 2° in 8'' SCT

*NOW ONLY*
**$99.50**

**LUMICON Rich-Field Viewer on C-8 with LUMICON 2'' star diagonal and 2'' eyepiece.**

The LUMICON Rich-Field Viewer fits **all** commercial Schmidt-Cassegrain telescopes. It has a high-performance coated achromatic focal reducing lens with 50mm clear aperture for **totally unvignetted viewing** with 2'' or 1¼'' eyepieces. It is available in several combinations depending on the eyepiece and field-of-view you desire (see chart below).

| | |
|---|---|
| **LUMICON Rich-Field Viewer** ..... | **$99.50** |
| Giant Rich-Field Viewer (10-14'') .. | **$250.00** |

| **Optional Eyepiece** | **TRUE FIELD** | **Price** |
|---|---|---|
| Tele Vue 32mm Plossl | 1.4° | **add $98** |
| Tele Vue 32mm 2'' Wide-Field† | 2.0° | **add $398** |
| Meade 40mm Wide-Field† | 2.6° | **add $498** |

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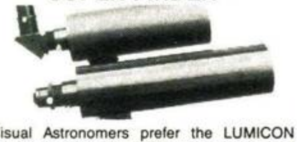

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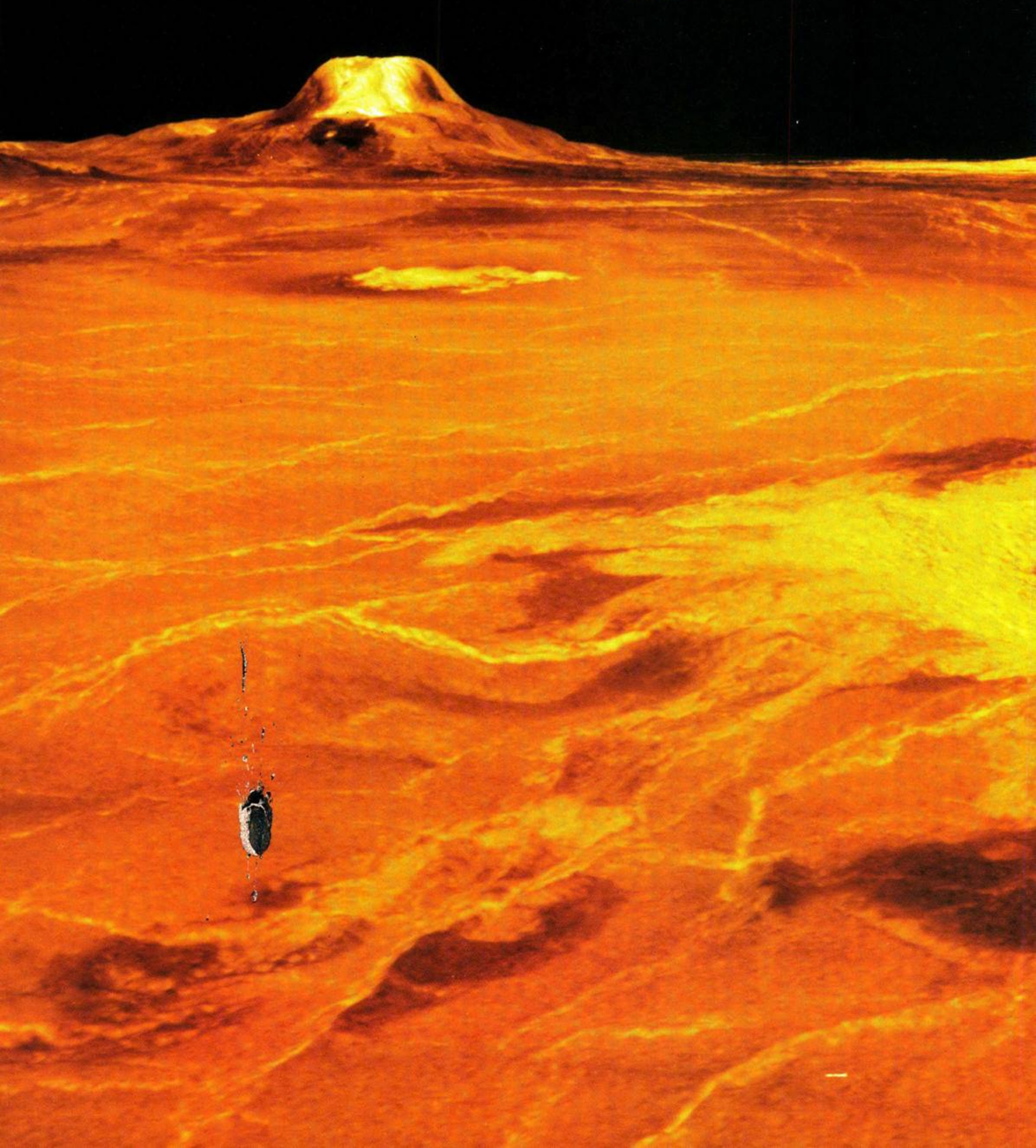
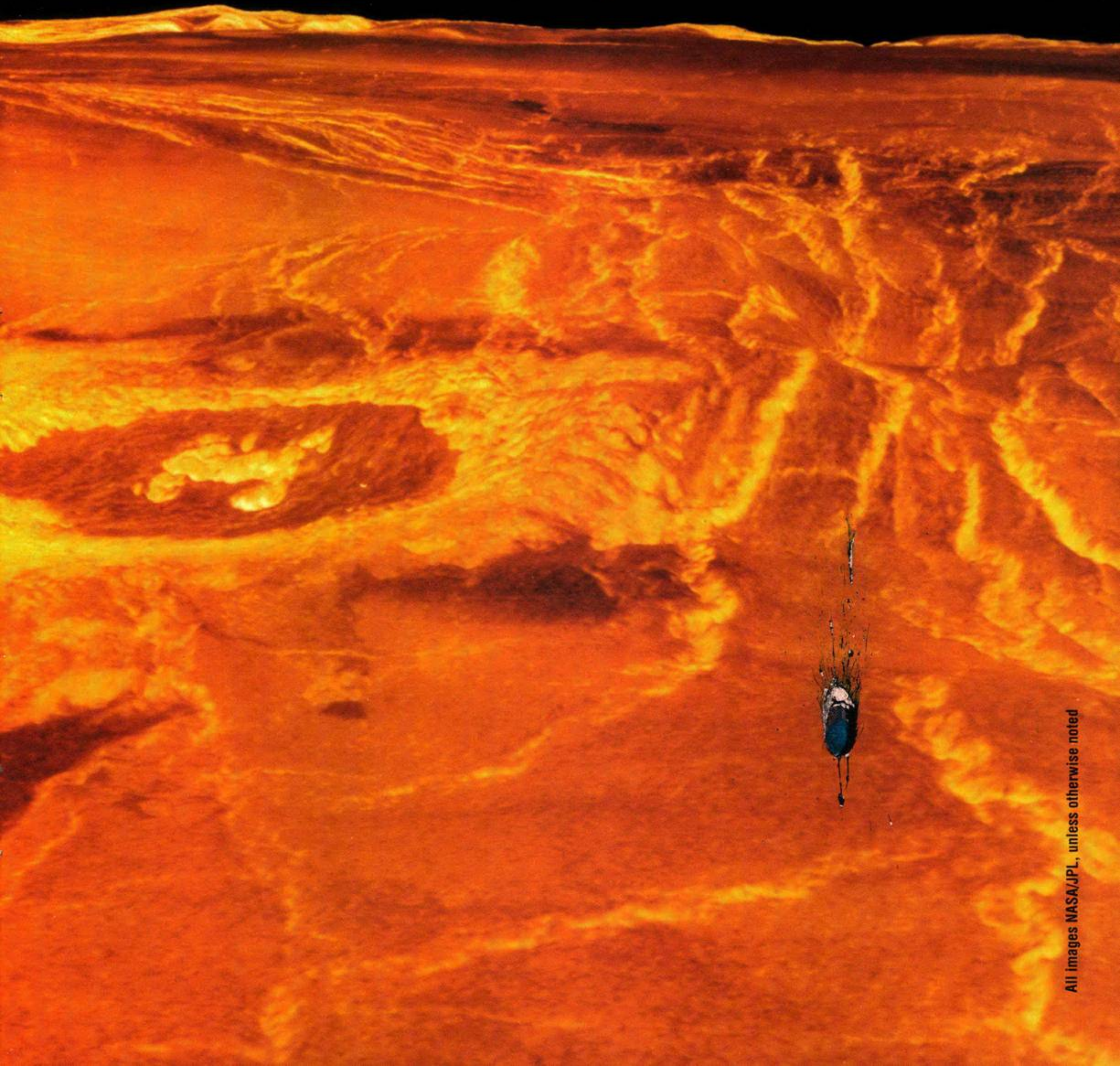
# Magellan



# Reveals Venus

The Magellan mission shows Venus to be a world with an intriguing past.

by Cordula Robinson

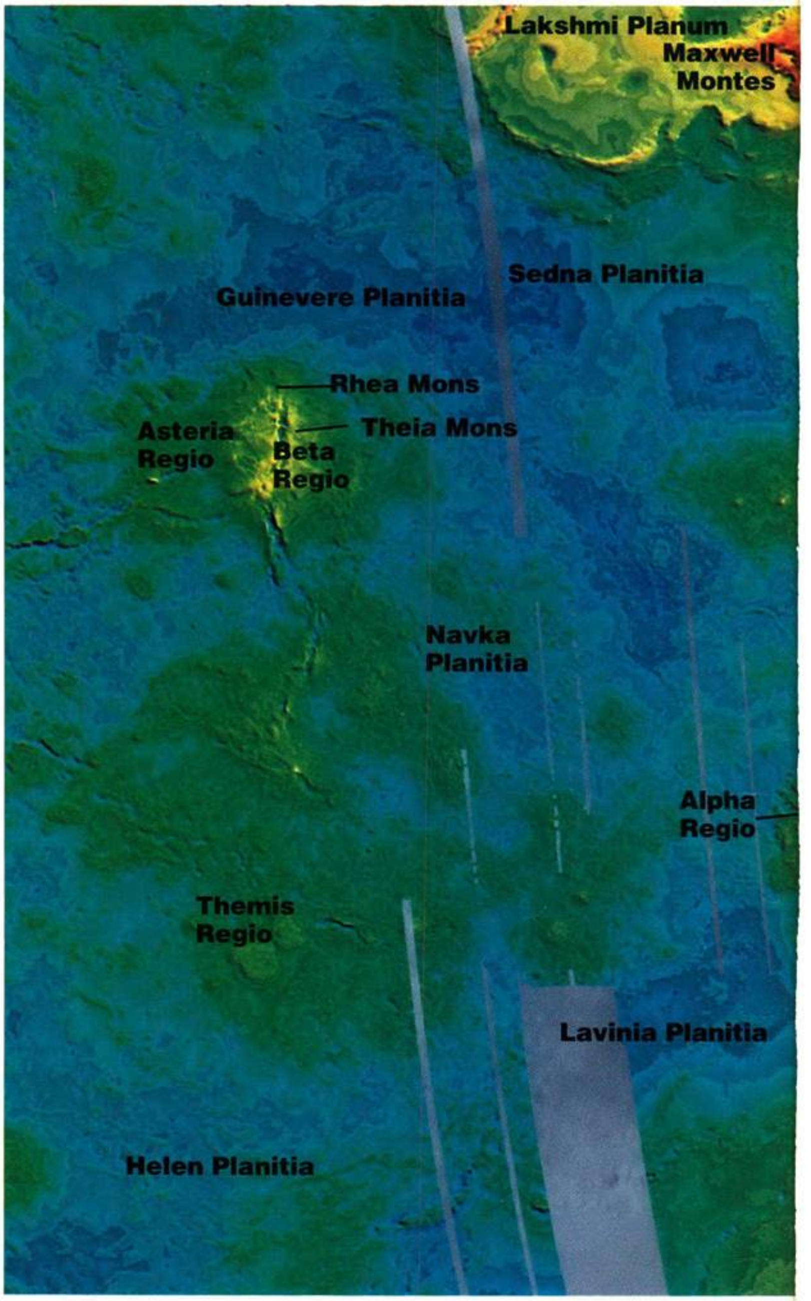


All images NASA/JPL, unless otherwise noted

Once called Earth's "sister planet," Venus has thrown planetary geologists a curve. It was considered kin to Earth because of its similar size, mass, relatively close distance, and solid surface, but it's considered kin no more. With the end of the Magellan spacecraft's five-year mission, scientists now realize that in a geological sense Venus has less in common with Earth than they believed. The spacecraft, launched from the space shuttle Atlantis in May 1989, produced one trillion bytes of data and has increased the number of named Venusian features from 300 to 1,000. In October 1994 controllers terminated the mission and sent the spacecraft plummeting toward Venus. The cause? Magellan had completed all significant mission goals and funding was running low.

Magellan leaves a legacy of data that will keep Venusian geologists busy "for decades," according to one scientist. The two major phases of the mission, radar mapping and gravity mapping, produced a more detailed global map of Venus than we have of Earth. They showed planetary geologists an amazing array of geological forms that often suggest processes quite different from those on Earth. "We realized we're looking at a geologically young surface," says Stephen Saunders, Magellan's Project Scientist. "And that surprised us." A dramatic event apparently resurfaced the planet some 300 to 500 million years ago, and since that time the planet has been relatively quiet in a geologic sense.

The inactivity leads to an intriguing question: Just what caused a surge in volcanic activity on Venus half a billion years ago? "Now, after Magellan, our view of Venus is completely different than it was before," says Maria Zuber, a planetary geophysicist at Johns Hopkins University and NASA's Goddard Space Flight Center. "It forces you to think of possible Venus histories that, before Magellan, geologists would have thought ridiculous," she says.



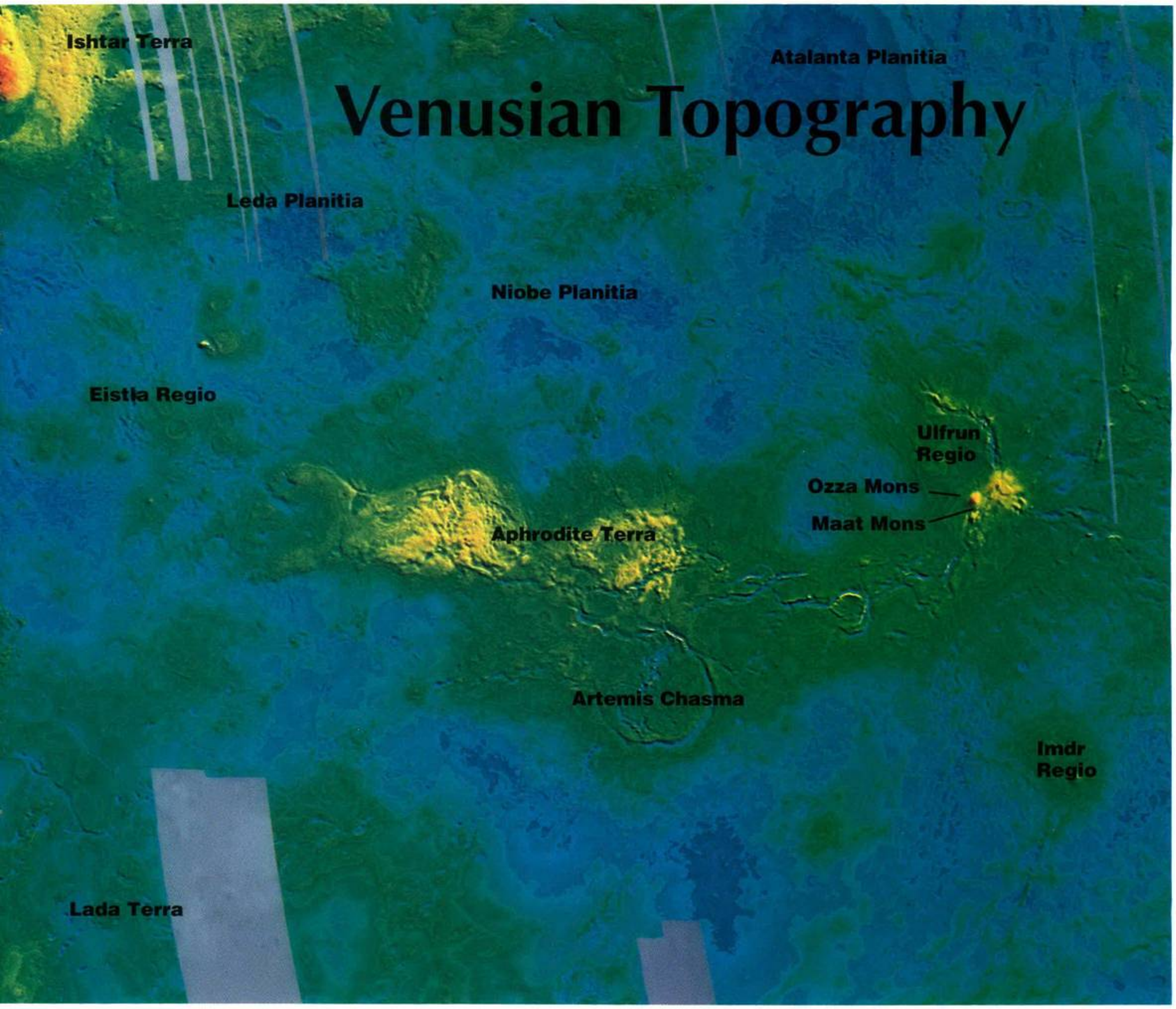
"You hear some scientists saying they are disappointed because Venus is so unlike Earth," says James Head, a specialist in comparative planetology and Magellan coinvestigator at Brown University. "To me, that's a rather Earthcentric view; the differences are the things that will ultimately tell us a great deal," he says. "If Venus had turned out to be exactly like Earth, that would've been big news! But because it hasn't, we need to ask ourselves how it differs and what this tells us about how Venus works."

### Magellan as Planetary Mapper

Understanding how Venus works began with the radar mapping phase of the mission on September 15, 1990, (see "What Magellan's Radar Sees," p. 37). Over the following two years Magellan mapped 99 percent of the planet's surface by bouncing thousands of pulses of radio energy each second through the thick veil of clouds enshrouding the planet. The radar reflected off the planet's surface and returned to the spacecraft, allowing a detailed picture of the surface to be constructed. When combined with altimetry data that measured the heights of various landforms, the radar data slowly gave us a detailed map of Venus. Additionally, the spacecraft collected radiometry data, providing astronomers with a global survey of possible variations in Venusian surface chemistry. Combining and correlating the three sets of information produces a detailed picture of nearly the entire surface of Venus. Pumpkin-orange false-color and three-dimensional computer processing by the Jet Propulsion Laboratory combined with the images create dramatic "flyover" renderings of major geological features on Venus (see pp. 32 and 33 and the cover of this issue).

But the first phase, *the radar mapping*, was only one aspect of the mission. In August 1993 Magellan performed a complex aerobraking experiment designed to

# Venusian Topography



**MAGELLAN'S TOPOGRAPHICAL MAP OF VENUS** shows the planet's highland "continents" (shown in false-color yellow and orange) such as Ishtar Terra, Aphrodite Terra, Alpha Regio, and Beta Regio, and low-lying plains (blue) such as Atalanta Planitia, Sedna Planitia, and Leda Planitia.

change its orbit from a highly elliptical one to a more circular one, giving it a range of 180 kilometers to 600 km above the surface of Venus. Aerobraking the spacecraft was a risky maneuver that relied on atmospheric drag to slow Magellan and keep it in orbit. But the process improved the quality of a second major phase of the mission: collecting gravity data (see "'Seeing' Below the Surface," p. 36). Using the spacecraft as a gravity probe allowed scientists to analyze variations in the gravity of the planet. When the spacecraft passed over a landmass, its gravity field increased or decreased, tugging the spacecraft accordingly. The tug changed the frequency of the radio signal sent from Magellan to Earth, revealing a so-called gravity anomaly. If the anomaly matches the amount of rock visible in the landmass, it implies the feature sits on a strong surface layer. If not, other forces must be active below the surface.

"These data will eventually help us sort out density variations in Venus' mantle which hold information on the style of convection in the planet's interior," says Zuber. "It also tells us the thickness of the crust." The gravity measurements showed Magellan scientists that Venus has geological structures created by movements in the planet's interior.

"The two types of density anomalies occur at shallow levels and deep levels," says Robert Herrick, a geologist at Houston's Lunar and Planetary Institute. "On Earth, mountains have roots." Supporting mountains whether on Earth or on Venus is a zero-sum game, Herrick explains. "If you have a high standing feature, it's an excess of mass, and you need a deficit of mass somewhere

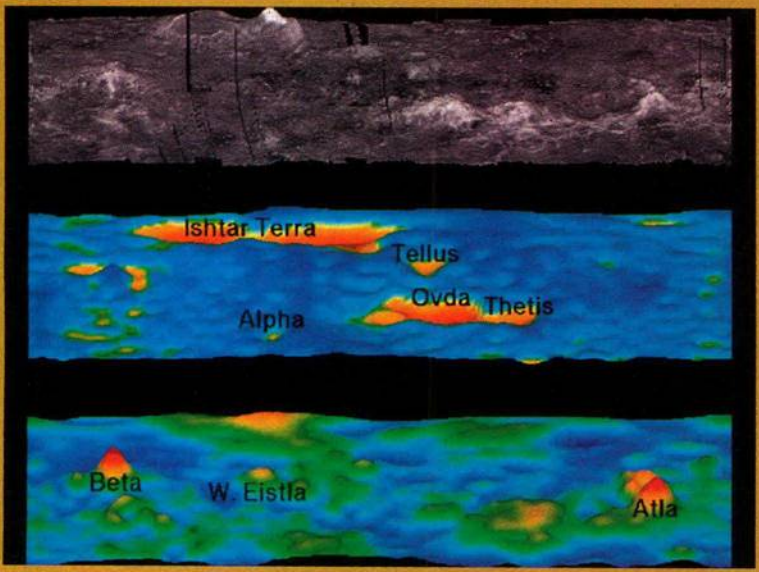
# "Seeing" Below the Surface

A three-layer perspective view of Venus (below) shows Magellan's view of global topography (top), density anomalies in the planet's lithosphere (middle), and density anomalies in the planet's upper mantle (bottom). By combining Magellan's gravity and topography data shown in the bottom two images, scientists look below the surface of Venus to see what supports the planet' mountains and volcanos.

Bright regions in the middle frame such as Ishta Terra, Alpha Regio, Ovda Regio, and Thetis Regio ar highlands sitting on thickened areas of low-density crust They're "like corks floating in an ocean of crust," a Magellan scientist Robert J. Herrick says.

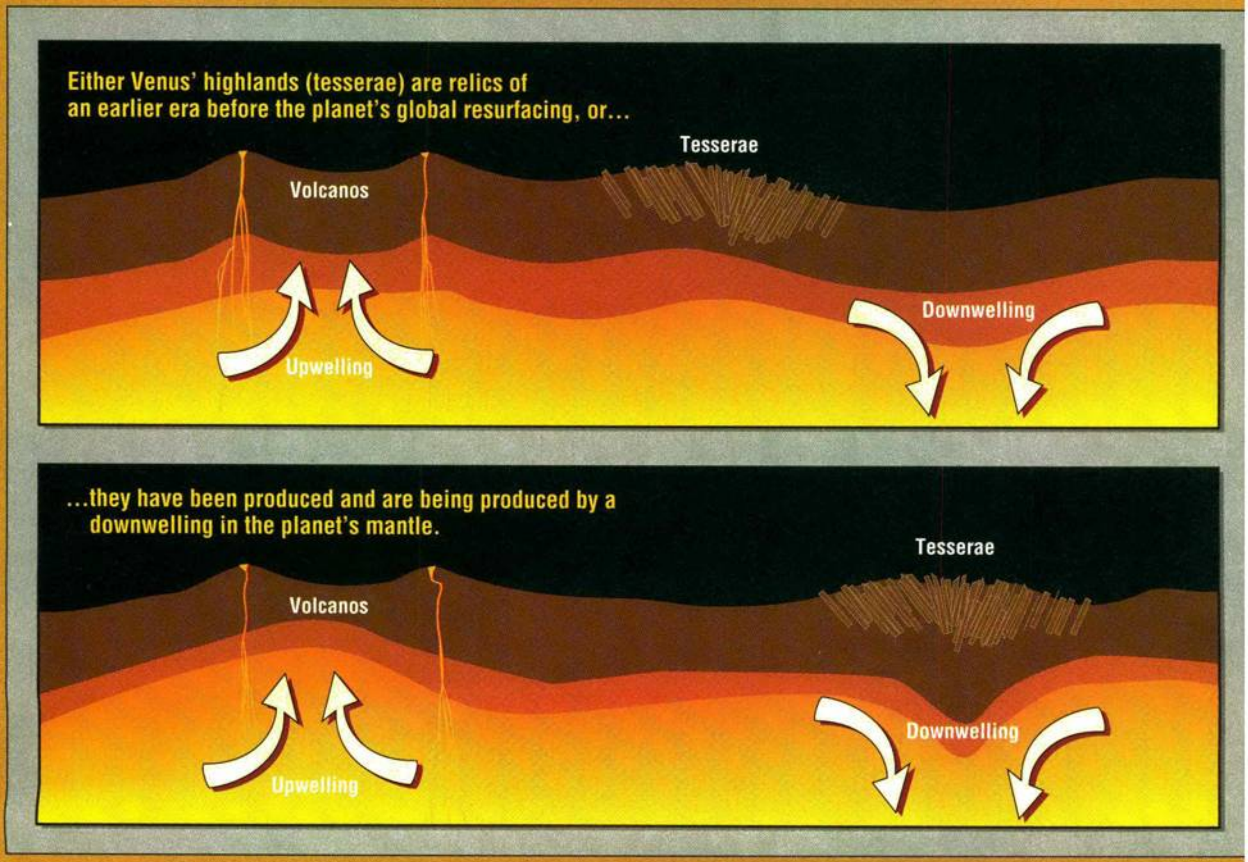
Bright areas in the bottom frame suc as Beta Regio, West Eistla Regio, and Atl Regio are volcanic areas supported by hot plume of material rising from deep i the Venusian mantle. "They're like a cor balanced on a vertical waterhose," say Herrick. They will be preserved as long a the energy from below continues upward When the energy falters, they will sink This is a simple view of how Venus works.

The planet experienced a global resurfacing 300 to 500 million years ago, coating the planet with lava. Venus' highland (tesserae) may have survived the event an may provide a clue to the planet's earlie history (below, top). Or, as some researchers believe, the highlands may hav been produced by downwelling in th planet's mantle (below, bottom), that continues to this day.



Ishtar Terra
Tellus
Ovda
Thetis
Alpha
Beta
W. Eistla
Atla

Robert R. Herrick, LPI



Either Venus' highlands (tesserae) are relics of an earlier era before the planet's global resurfacing, or...
Tesserae
Volcanos
Upwelling
Downwelling
...they have been produced and are being produced by a downwelling in the planet's mantle.
Tesserae
Volcanos
Upwelling
Downwelling

ASTRONOMY: Lee Vande Visse

else to make up for it. We transfer the same process to geological features on Venus, meaning a mountain on Venus has a low-density crustal root underlying it. Topography could also be supported with a plume of material welling up underneath it."

### A New Planet Emerges

The abundance of data returned by Magellan has not yet been analyzed thoroughly, but planetary geologists have worked with the data enough to see striking differences between Venus and Earth. There were the obvious differences known before Magellan, of course, like the fact that Venus' surface temperature approaches 500° Celsius, its surface pressure is 90 times that of Earth, the planet has no water, and the atmosphere is a greenhouse gone wild, with sulfuric acid clouds and an overabundance of carbon dioxide.

It's not an inviting place for life, but this parched, suffocated globe may be home to an unusual mineralogy. The first hint of this came when researchers saw that many mountains on Venus appeared to be bright in radar images. On Earth, radar-brightness can result when radar bounces off moist soil. Venus lacks water, however, so planetary geologists sought another answer. Gordon Pettengill of the Massachusetts Institute of Technology, Principal Investigator for Magellan's radar experiments, suggested some metallic minerals reflect *radar as well* as water. The leading candidate: pyrite, known best on Earth as "fool's gold" for its superficial resemblance to gold and the legacy of shattered hopes in the California Gold Rush.

After Pettengill suggested that a pyrite-rich material covered many of the Venusian mountains, John Wood of the Smithsonian Astrophysical Observatory checked to see if this was possible. Wood investigated which surface chemistries would be stable under Venusian conditions using information about surface chemistry and the constituents of Venus' atmosphere. Wood agrees that pyrite would be stable in the weathered surface material high on the mountaintops, but not down on the plains, where temperatures and pressures are higher.

The issue may be more complex, however, according to Peter Ford, a physicist and Magellan scientist at the Massachusetts Institute of Technology, who believes that other minerals may be responsible. "For example, we may be looking at some ferroelectric materials," says Ford. "Something quite exotic that doesn't exist commonly on Earth and retains this oddly reflective property at very high temperatures like those on Venus. You need only about 1/100th the amount of exotic material to achieve the same result, making it far more plausible."

### Craters and Volcanos

Some planetary geologists have used the arguments concerning Venusian mineralogy to recognize the sequence of major events in the evolution of Venus. They can tell which landforms are old because of the weathering; younger landforms do not show the kinds of weathering the older ones do. For example, Maat Mons, the largest volcano on Venus, appears to have undergone a recent surge of volcanic activity; radar-bright (blocky, unweathered) material coats the volcano's flanks and summit. Ozza Mons and Theia Mons may also have undergone recent activity, whereas other volcanos such as Tepev Mons are clearly extinct. The gravity data also support this, showing that the volcanos thought to be active are being supported by plumes of upwelling material through the planet's crust.

## What Magellan's Radar Sees

It's tempting to slip into thinking of Magellan's pumpkin-orange images as true-color photographs of Venus' surface. They are color-coded radar images, however, that resolve details as small as 120 meters. Magellan's synthetic aperture radar, which can penetrate the thick veil of clouds enshrouding Venus, imaged a swath between 17 km and 28 km wide.

The high-gain antenna emitted thousands of pulses of radio energy each second across the swath of Venus lying from 294 km to 8,543 km below it. (The spacecraft's orbit was elliptical.) The pulses bounced off the Venusian features and returned to Magellan, where they were received by the antenna and transmitted back to Earth. An altimetry antenna sent signals to the planet to measure the height of various features. By combining the data and producing a map (and adding color), the Magellan science team provided the alluring images on these pages.

The entire Magellan data set, cleaned of artifacts and electronically stored on CD-ROM, is available from NASA. Interested computer users can find out more (and sample the images) by accessing the World Wide Web, NASA home page at: http://stardust.jpl.nasa.gov, or sending electronic mail to: request@nssdca.gsfc.nasa.gov.

Weathering patterns alone do not reveal much about Venus' past. Scientists also looked at the cratering record, usually one of the best gauges of the age of a planet's surface. Impact craters cover the hard surfaces of planets and satellites throughout the solar system. Their frequency, size, and distribution allow geologists to approximate the date of the planet's surface. Surfaces saturated with impact craters of all sizes are three to four billion years old, and those with only a few small impact craters are young. The surfaces of Mars and the Moon show a wide range of ages. Venus, however, does not.

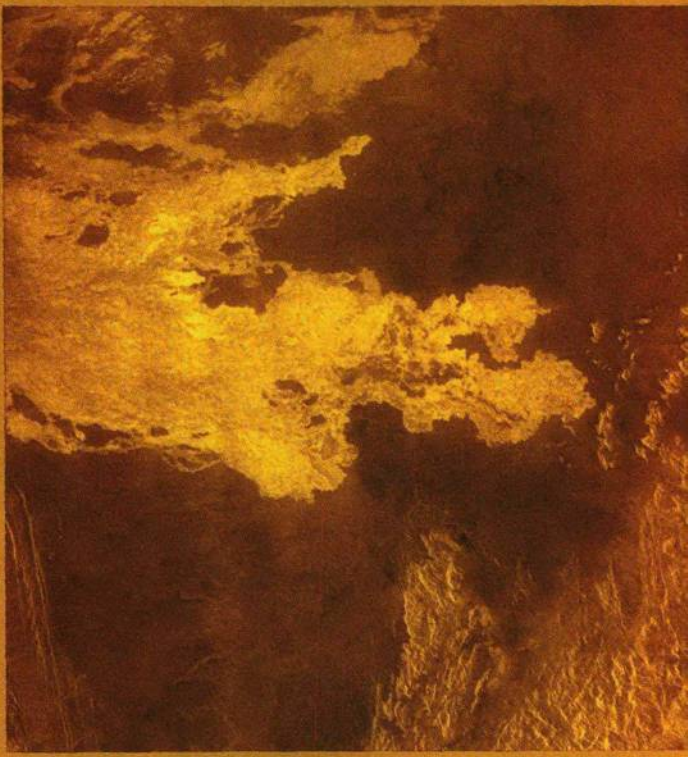
But, says Head, "One of the major findings by Magellan is that you can't distinguish differences in surface ages on Venus by the cratering record alone." This is because the 900-odd craters on the planet lie scattered at random over the entire planet. Older or younger areas can't be judged by crater counting.

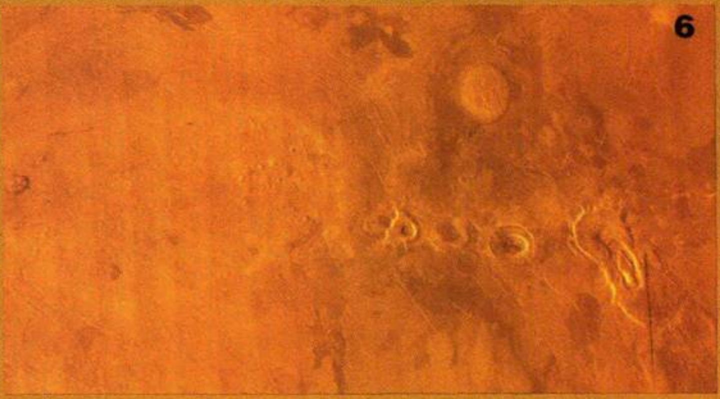
Venus has fewer craters than you can see on the Moon with a small telescope. Few in number and fresh in appearance, the craters suggest Venus' surface as a whole is youthful, in geological terms. The impact cratering record shows clearly that most of the geological activity on the planet has occurred in the last 300 to 500 million years. This means that either some major

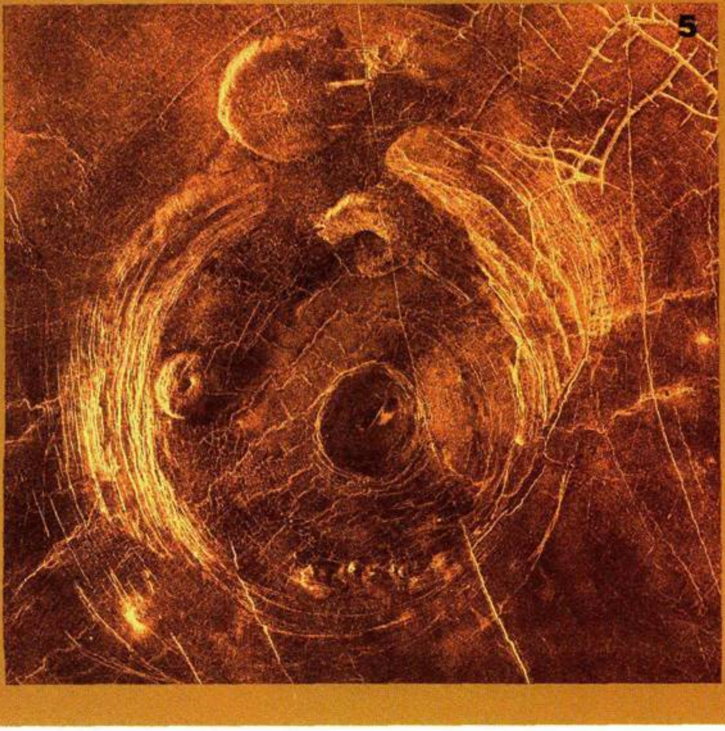
# Craters, Coronae, and Pancake

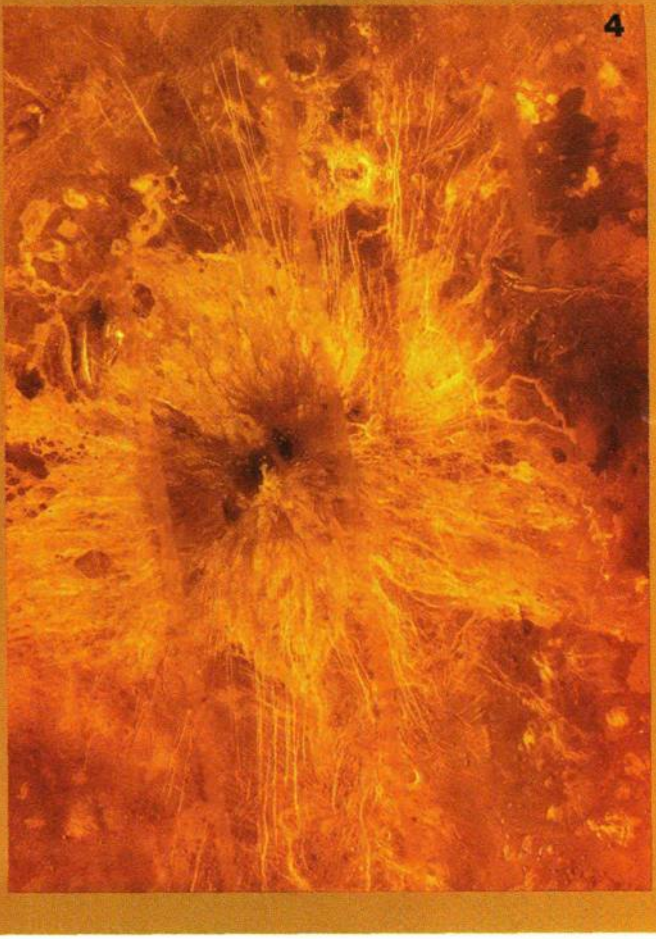
Venus displays a wide range of geological features; some, like shield volcanos, are familiar, and some, like the planet's peculiar coronae, are unique in the solar system.

Eistla Regio (1) contains tesserae, fractured highlands that represent the planet's older material not covered by younger flows of lava. Mead Crater (2) is the largest impact crater on the planet. Pancake domes east of Alpha Regio (3) are volcanos formed by thick lava oozing from a central vent. Ushas Mons (4) is a 2-km-high volcano marked by bright lava flows and fractures. Aine Corona (5) was formed when a rising plume elevated the surface above it, which then collapsed when the plume activity ceased. A complex region southeast of Beta Regio (6) contains diverse volcanism; from left to right: a field of small volcanos, a scalloped dome volcano, a volcanic caldera, and another scalloped dome. The features were probably created by a single complex of volcanic activity beneath the planet's crust.









# Domes

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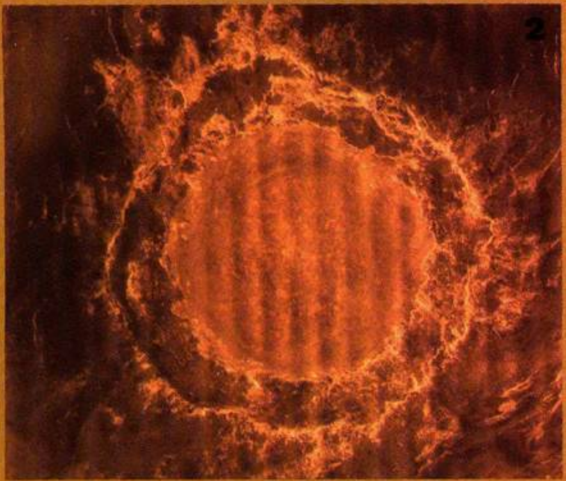

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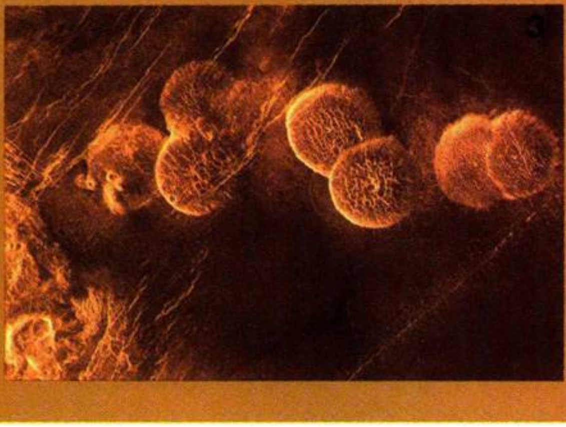

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event must have wiped the planet's surface clean 300 to 500 million years ago, a scenario suggested by Gerry Schaber of the U.S. Geological Survey, or a slower, more piecemeal resurfacing has occurred since that time. Which of the two mechanisms actually happened is hotly debated.

Head and Zuber are astonished with the implications of the first mechanism. "It's an incredible thing to ponder: Your close planetary neighbor turned itself completely inside-out just a few hundred million years ago," says Head. "This is big news — the planet's entire crust and lithosphere turning itself over. It certainly makes a strong case that catastrophic events are in the geological records of planets and it ought to make us think about the possibilities of such catastrophic events in Earth's past," he says.

"Many of us are flabbergasted by this resurfacing event," says Zuber. "When the idea first arose everyone sat back and said 'yeah, we'll wait for the data to come in and the idea will be laid to rest.' But the more everyone looked at the cratering record, the more clearly it appeared that a catastrophic resurfacing indeed may have taken place over most of the planet."

On the other hand, Roger Phillips of Washington University in St. Louis believes low-level volcanism operating over a longer period may have resurfaced the planet piecemeal. "The evidence for the global event is not terribly strong," says Phillips. "The whole thing is suffering from the fact that there are so few craters on the planet. Statistical approaches are always lousy, and more and more people are coming up with evidence that geological features on the planet have different ages. The answer is still a long way off."

The cratering record is limited to medium-sized and large impacts because small impactors burn up in Venus' thick atmosphere before they strike the surface. Hence, Venus lacks the numerous small craters that would help scientists choose between catastrophic or piecemeal resurfacing.

## The Venus of Tomorrow

Though they captured much of the immediate attention from Magellan scientists, volcanos and impact craters are small relative to the planet's size. As the images piled up, planetary geologists began to assemble a clearer picture of how Venus works as a planet. The greatest difference between Venus and Earth is the dominant mechanism by which the planets construct surfaces, shift crusts, and finally stabilize. Earth's primary method is plate tectonics, which moves the continents around in response to convective processes deep in Earth's mantle. Convection is the most efficient way the inside of a planet can transport heat to the outside. Hot material rises to the surface, causes volcanism, and cools off. The cooler material sinks into the mantle by subduction. This process leads to great surface activity where the plates meet, as the "ring of fire" along Earth's Pacific Rim attests.

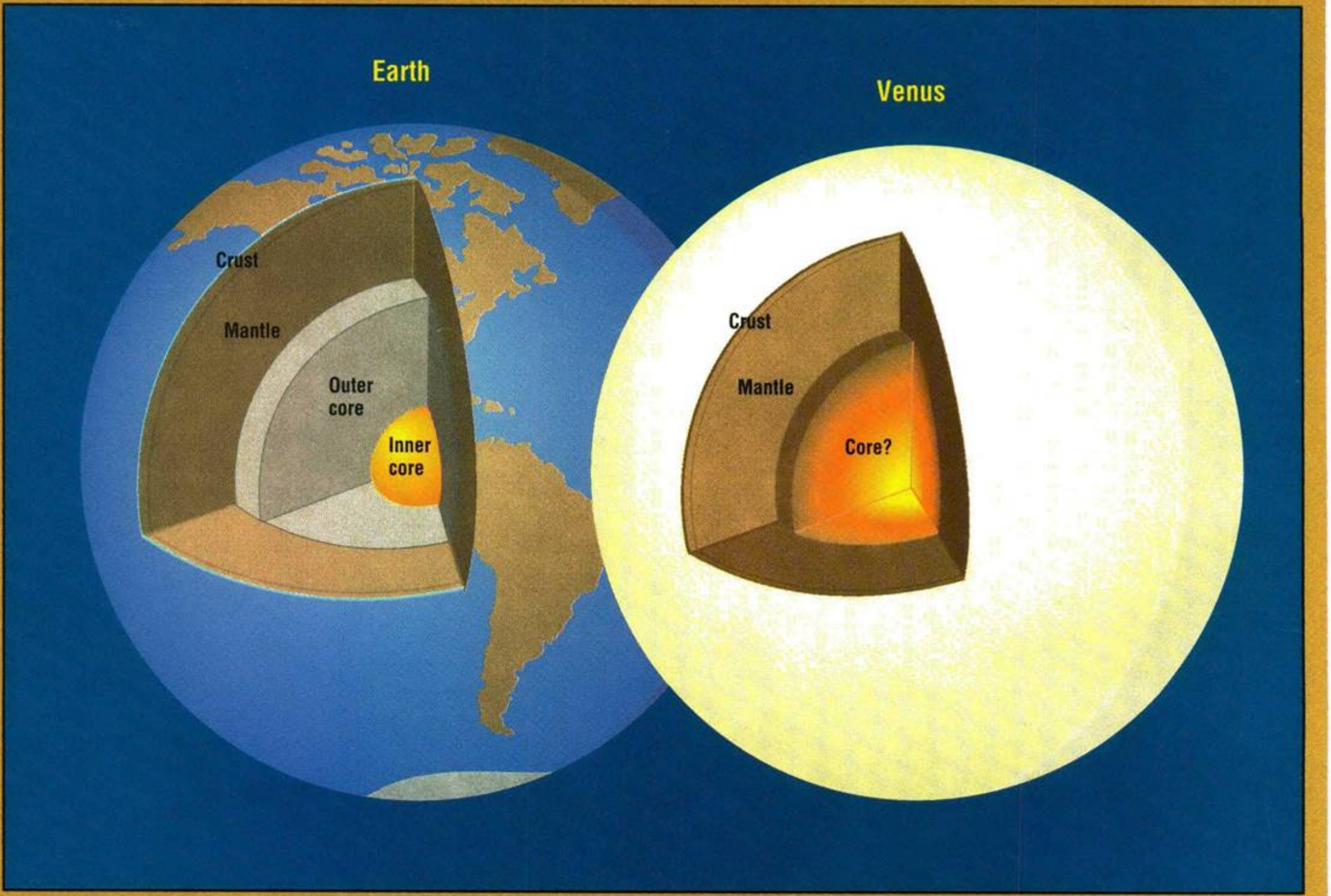
But Venus appears to be different. Detailed images from Magellan suggest the planet is encased in a thick, one-plate shell. "We know the surface crust is basalt," says Head, "but we don't know how thick it is." The planet's crust may be 20 km or more thick and its lithosphere, the region of mantle and crust that acts as one giant plate, about 50 km thick.

"Before Magellan we thought the lithosphere was

# First Cousins, At Best?

Is Venus Earth's "sister planet"? Hardly. Beyond the gross geological properties (both planets are rocky, about the same size and density, and relatively close to each other in the solar system), the planets have very little in common. They are first cousins, at best.

Earth has a thin layer of crust, a thick mantle, a molten outer core, and a solid inner core. Venus, it turns out, has a thicker crust than scientists thought, a thick mantle, and perhaps a core. The ways the planets work are quite different: Earth's central mechanism, plate tectonics, does not operate on Venus. Instead of plate tectonics, which is a horizontal process, Venus' activity is vertical, with upwelling and downwelling of internal heat providing most of the surface change. This results in an abundance of volcanos on Venus, some of which resemble those on Earth (for example, Hawaii's volcanos), but others take on more exotic forms unique to Venus.



ASTRONOMY: Lee Vande Visse

extremely thin," says Zuber. "Now we know it's thick over most of the planet."

Gravity data support this view, indicating a strong, stiff outer rind of rock that supports most of the planet's topography. But why does Venus lack plate tectonics? The planet may have been too cool long ago to start the process of moving plates. Or if, as some researchers suggest, water is needed for the process of plate tectonics, perhaps the lack of water on Venus prevented subduction.

"One problem is that almost nobody understands how plate tectonics starts," says Head. "Once a slab of basalt sinks 100 to 200 km it undergoes a phase change and begins to pull downward. No one knows how a slab moves down to that depth, so it complicates the understanding of whether Venus might have once had plate tectonics," he says. "But perhaps Venus built its crust vertically, bringing up rock and piling it on top of other rock, and the planet has never had plate tectonics. We don't yet know."

Even if Venus now lacks plate tectonics, it offers telltale signs of upwelling and downwelling. The planet appears to work vertically rather than horizontally. The hot plumes of material rising up from the mantle are marked by volcanos, which are everywhere. They range in size from domes a few kilometers across, which appear all over the planet and often in dense swarms, to huge shield volcanos dozens of kilometers across that are usually found at the tops of broad rises.

Another volcanic feature, the corona, is a large circular feature found only on Venus. Hundreds of kilometers across, coronae are heavily fractured and are sometimes surrounded by a trench. They are thought to form when a volcanic plume rising from the planet's mantle first lifts and then relaxes a circular region, causing cracking as the region falls back. Pancake domes are steep-sided hills that may form from thick lava that oozed onto the surface slowly through a central vent. Canali, or channels, are riverlike features where lava once flowed. One, called Hildr, is longer than the Nile River, extending nearly 7,000 km. They almost certainly were formed from surface erosion by hot, runny lava because water cannot exist under current conditions on Venus.

Upwelling and the resulting volcanism, then, permeate regions of Venus. The question for planetary geologists is, Where does Venus have downwelling? A possible site is the planet's tesserae: rugged, deformed highland mountains that extend for as much as thousands of kilometers and cover almost 10 percent of the planet. They may have formed from material dragged into a zone of downwelling, a cold spot, which deformed the surface (see diagram on p. 36). However, other scientists dispute this, claiming that either the material piled up and was deformed by gravity over long time periods, or that the tesserae are remnants of an older surface of Venus left unburied by the global resurfacing event.

"Tesserae could be the witnesses to the global resurfacing event," says Head. "Judging by the cratering, they are not much older than the flooded plains. So this suggests you had tremendous deformation of the crust going on close to the same time as the large-scale volcanic resurfacing event. These may be the remnants predating the big event." Herrick thinks the best evidence for the older age of tesserae comes from analyzing the craters on them. "There are about 10 percent more craters on the tesserae and they are somewhat more deformed than craters elsewhere on the planet," he says.

Other areas of downwelling may exist. For example, the edges of some coronae resemble subduction zones on Earth. But the most radical possibility for downwelling on Venus comes from the work of Donald Turcotte of Cornell University. He suggests that subduction may have caused the global resurfacing event itself. Turcotte believes the shell of Venus had grown increasingly thick, trapping and building up heat within the planet's interior. As the internal heat rose, molten lava accumulated until a critical point came, and the planet was flooded with lava that resurfaced it more or less all at once. Then with the heat released, the crust grew thick and stiff again. And this mechanism for global resurfacing may be cyclical: Venus may have experienced several such resurfacing episodes and may yet display another.

Head suggests the vertical nature of building Venus' crust may have aided such a catastrophic resurfacing. "If you bring up large amounts of basalt from the mantle and pile up a thick crust," he says, "all hell breaks loose, geologically speaking. The surface buckles, lava oozes up and repaves it. You destroy the old craters, compressing and deforming them, and cover them over with lava. You've reset the age of the planet's surface."

## What's Next for Venus?

With Magellan dead, the prospects for studying Venus lie chiefly in the vast store of mission data that remains to be analyzed. But some planetary geologists are already proposing a new mission to return to Venus, perhaps a launch as soon as 1997. Called Discovery-ВЕНЕРА [Venera] Surface-Atmosphere Geochemistry Experiments, the joint U.S.-Russian mission would send a 4,175-kg spacecraft to Venus and land a 650-kg scientific package on the planet's surface.

"We need to study the composition of key aspects of Venus' geology," says Brown University's James Head, one of the project's originators. The mission would focus on tesserae, crater ejecta, and material from the planet's highlands and lowlands, as well as examine constituents of the planet's atmosphere and how they interact with the surface. The project would also carefully study Venusian weathering. The spacecraft would accomplish these goals with an optical atmospheric spectrometer, an imaging spectrometer, a neutron probe and gamma-ray spectrometer, and an alpha-proton X-ray elemental analyzer.

"We want to know what the crust is made of, how much water the lower atmosphere contains and what the tesserae are made of, and examine the mineralogy and weathering of the surface material," says Head. "And if this mission moves ahead, we expect to do it."

"We still don't understand Venus very well right now," says Zuber. "We need to be extremely open-minded about what we're seeing and the possible explanations behind it."

For all the wonders it has revealed, Magellan has still opened only the first pages in the book of Venus. In the wake of the mission, scientists are analyzing the store of Magellan data that remains to be looked at. Discoveries will stack up, models will be proposed, papers will be published, and glimpses into our sister planet will become deeper understandings. We may see a joint U.S.-Russian mission to Venus (see box above). "We're left with some big questions," says Saunders. "What went on in the 90 percent of Venusian history before the resurfacing? Did Venus have plate tectonics? Was Earth's early history similar to that of Venus? Did Earth experience periods of violent crustal overturn? How did the highlands on Venus form? What is the interior structure of Venus? Is the planet seismically active? These are the kinds of things we would like to know." □

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*Cordula Robinson is a postdoctoral associate at the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts. A geologist, she specializes in remote sensing.*

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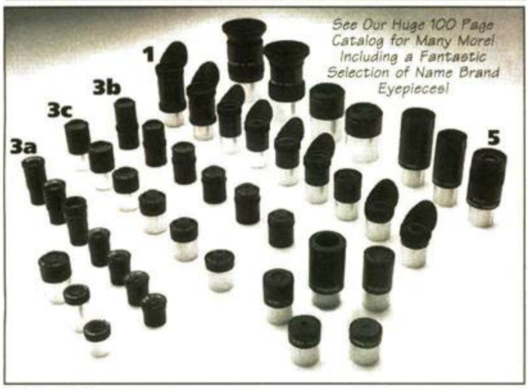
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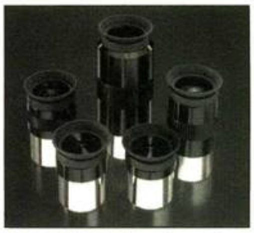

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#8481 ***$99.95*** (3.45)

***SR-44 Batteries (pkg. of 2)*** #2360 ***$5.95*** (1.79)

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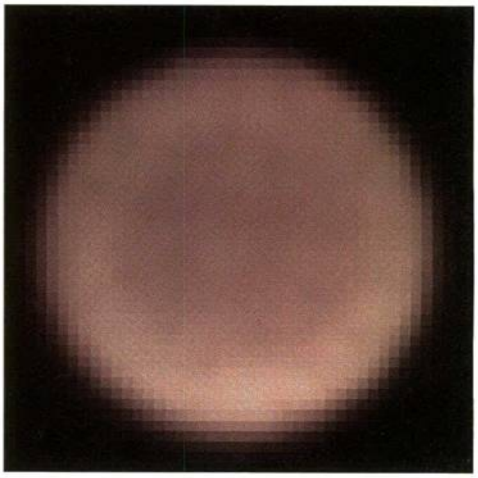
# Hubble Maps Titan's Hidden Landscape

Titan, the smog-shrouded big moon of Saturn, finally has a map, thanks to the Hubble Space Telescope.

by Robert Burnham



**BRIGHT WATER ICE AND DARK HYDROCARBONS** mark the newly discovered surface features of Titan, Saturn's largest moon. Images like the one above, a snapshot of the atmosphere taken with Hubble, have helped scientists pierce the smog hiding the surface.

A team of planetary scientists led by Peter Smith of the University of Arizona has used the extraordinary resolving power of the repaired Hubble Space Telescope to discern landforms and features on the surface of Titan, Saturn's largest moon. The result is the first map of a hitherto invisible landscape.

Titan is huge for a moon and therefore has a *lot* of surface. If it didn't circle Saturn, Titan could be a planet in its own right, being slightly larger than Mercury and nearly as big as Mars. It has about as much surface area as Europe, Asia, and Africa combined. The flyby visits of Voyagers 1 and 2 in 1980 and 1981 showed that Titan's atmosphere is 50 percent heavier than Earth's and contains mostly nitrogen with small amounts of methane, ethane, and other hydrocarbons. Alas, the Voyagers also found that the atmosphere was filled with an orange smog, virtually opaque to the spacecrafts' cameras.

To peel away the smog, Smith's team resorted to a clever trick. They used the Hubble's Wide-Field/Planetary Camera 2 to image Titan at a near-infrared wavelength of 9400 angstroms. At that wavelength Titan's atmosphere is partially transparent, at least between roughly 40° north and south latitudes. (Unfortunately, the surface in the polar regions can't be seen because the line of sight passes through too much hazy atmosphere.)

The scientists snapped 50 images of Titan as it circled Saturn in its 16-day orbit. (One of these is on this page.) Smith's team then processed the images to remove the varying effects of the atmosphere, leaving only the invarying image of the landscape beneath the haze. The results reveal a world with at least one bright feature and one large dark area (color images far right). Each pixel in the image covers about 290 kilometers. The bright feature is about as large as Australia and lies mostly on the leading hemisphere; the large dark area sits almost dead center on the moon's trailing hemisphere.

What is the surface like? The temperature at the ground is an extremely chilly 94 kelvins (−290° F). Methane can exist there as a solid, a liquid, or a gas, much as water does on the surface of Earth. Thus there could be methane clouds, snow, rain, or even glaciers, together with pools, lakes, or seas of the stuff.

At one point, scientists thought that Titan had a global ocean of methane. But in 1992, a group led by Dewey Muhleman of the Jet Propulsion Laboratory used NASA's Goldstone antenna to bounce radar pulses off Titan. Muhleman's group found that the surface didn't reflect radar the way a global ocean would. Their evidence showed that any pools of liquid would have to be patchily distributed and water ice could be common on the surface.

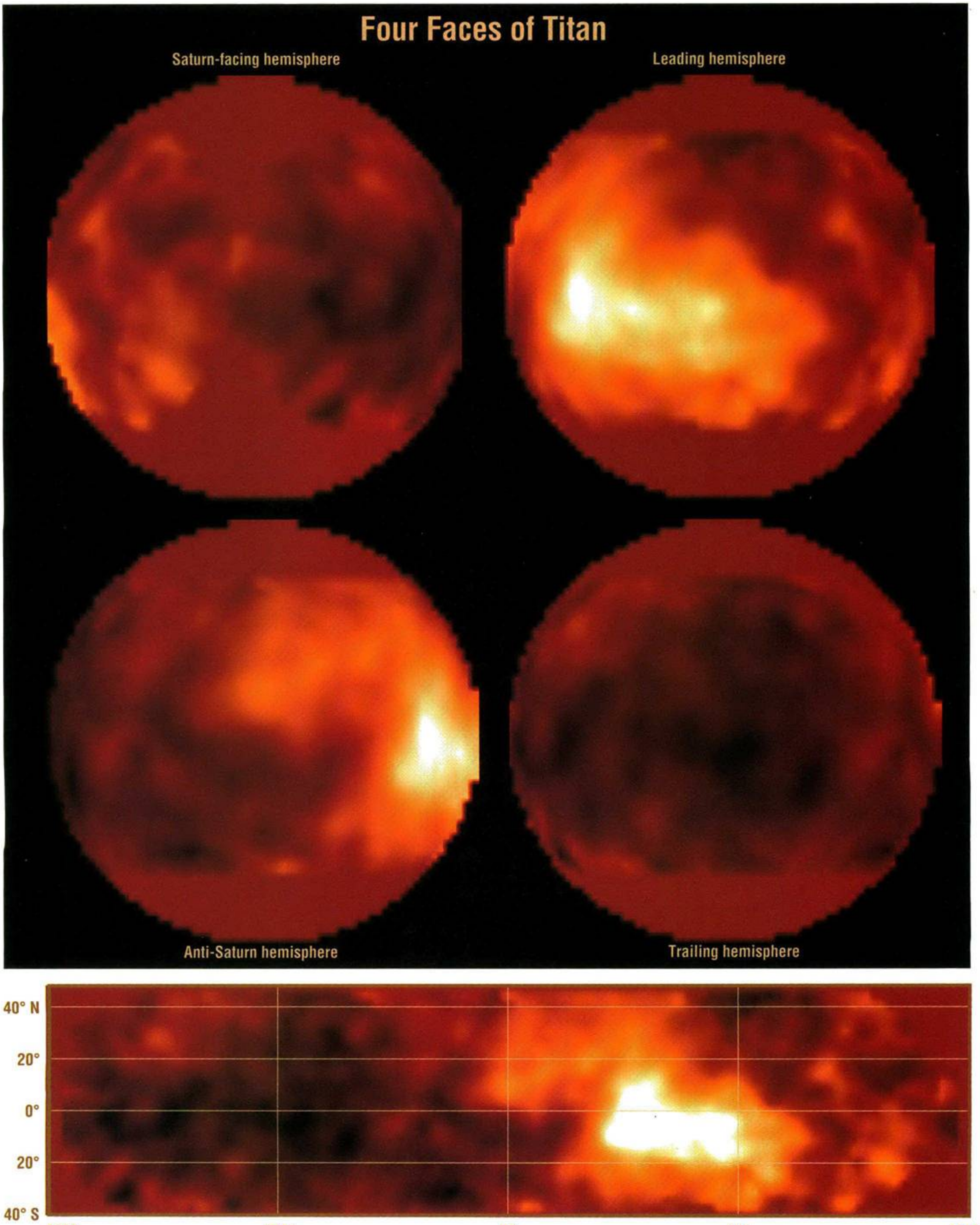
At about the same time, ground-based detections of the surface by Mark Lemmon of the University of Arizona and, independently, by Caitlin Griffith of NASA's Ames Research Center led scientists to suspect that Titan rotates synchronously, that is, it rotates once in the same time it takes to go around Saturn. The new images appear to confirm this.

It's too early to say what kind of landforms these features are, says Smith. But he notes it would be reasonable to expect impact craters and geological structures like those found on the surfaces of other Saturnian moons.

The bright feature, he remarks, might be a water-ice mountain or high continent washed free of the dark hydrocarbon goo that probably coats much of Titan's surface. (The fact that Muhleman's team got a strong signal return from the region of the bright feature supports this interpretation.)

But if it's a mountain, it presents a puzzle. A mountain would alter Titan's center of mass and the moon would slowly turn to point the feature toward Saturn. Yet it doesn't lie on the Saturn-facing hemisphere. This may mean the feature formed relatively recently, at least in geological terms, or perhaps there is some other explanation scientists don't yet understand.

The new map is delighting the Cassini science team. When that mission, scheduled for launch in 1997, gets to Saturn in 2004, it will send a probe (named Huygens for Titan's discoverer) to land on Titan. According to present plans, drawn up before the map became available, the Huygens probe would land just to the northwest of the bright feature. The scientists working on the Huygens probe will now be poring over the new map and refining their plans for the landing. □



Four Faces of Titan

Saturn-facing hemisphere
Leading hemisphere
Anti-Saturn hemisphere
Trailing hemisphere
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20°
0°
20°
40° S
180°
270°
0°
90°
180°

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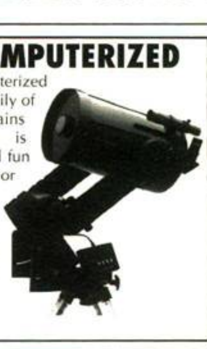

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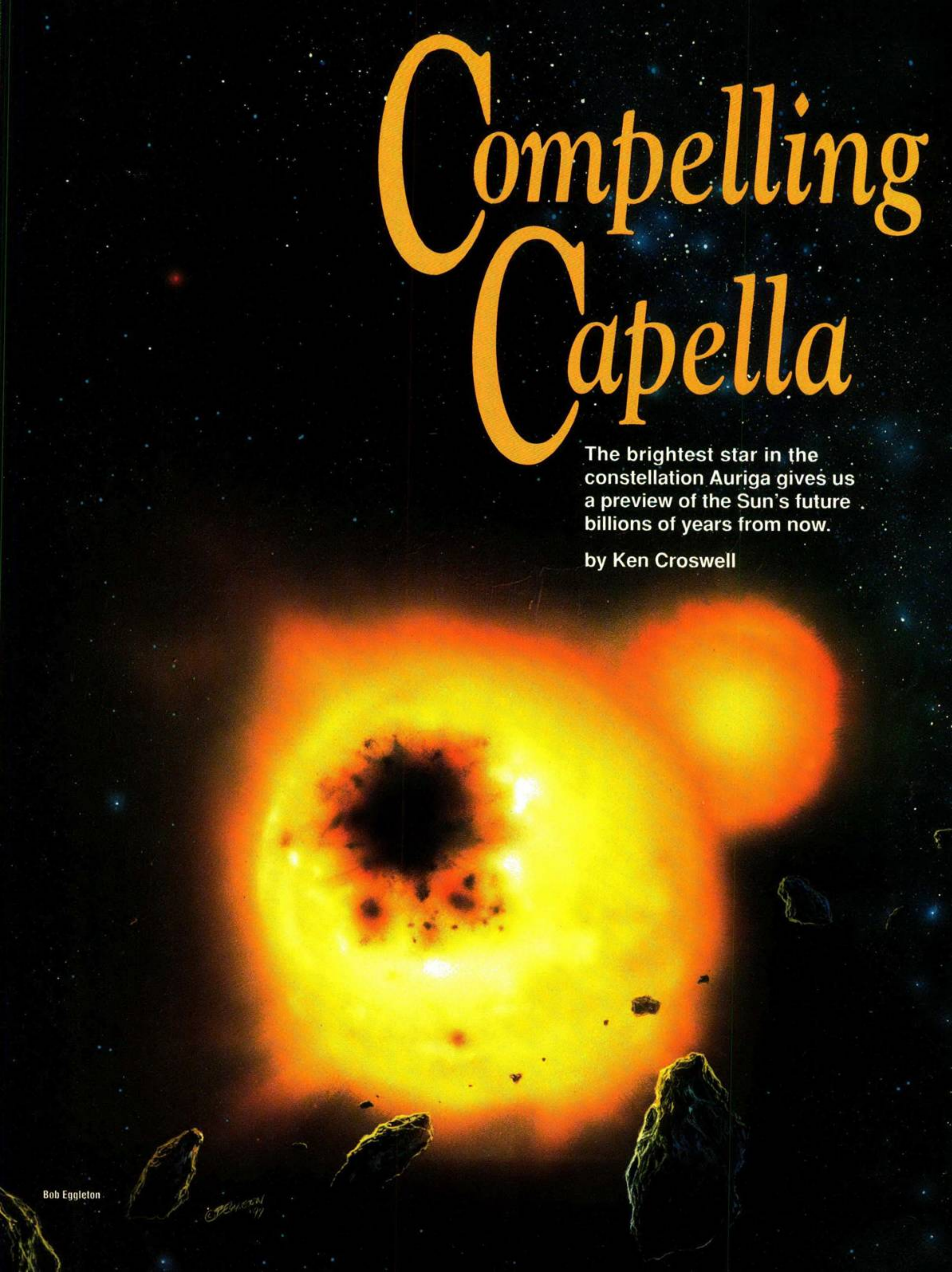
# Compelling Capella

**The brightest star in the constellation Auriga gives us a preview of the Sun's future billions of years from now.**

**by Ken Croswell**



Bob Eggleton

Capella is a superlative star, being the sixth brightest star in the night sky. It's also northernmost of the 25 brightest stars visible from Earth. This northerly position means that observers in the United States can see Capella nearly year-round. Whereas most bright stars are at their best during only one or two seasons, Capella lights the early evening sky from September through June.

Capella's brilliance and position attract observers, but so does its color. Capella is a yellow star with a spectral type of G, just like the Sun, and is the only bright G-type star in the night sky visible from most of North America.

Despite the similarity in color, Capella actually differs greatly from the Sun, for Capella is a giant star several times larger than the Sun. Because of its size, it radiates over 100 times more light into space than the Sun does. If we viewed the lesser light of the Sun from the 43 light-year distance of Capella, we wouldn't see much. Our star would appear as a 5th-magnitude speck, barely visible to the naked eye.

L. H. Price

**THE BRIGHTEST STAR IN AURIGA**, Capella shines like a beacon at the top of the picture. The magnitude 0.1 star may be a quadruple system containing two yellow giants and two red dwarfs.

Giant stars like Capella are in a more advanced stage of their life cycle, or evolution, than the Sun, so they provide a window on the future life of Sun-like stars. Giants have evolved from stars born with less than eight times the Sun's mass, stars that constitute the vast majority of the Milky Way Galaxy. (The few stars born with more than eight Suns become supergiants rather than giants and eventually explode as supernovae as they die.)

Gianthood therefore represents the future of many stars, including Sirius, Procyon, Vega, Alpha Centauri, and the Sun. But because the giant stage is a short phase of a star's life, giants are rare. They account for less than one percent of all stars in the Galaxy. For example, more than a thousand stars lie within 43 light-years of the Sun. Yet only three in this region are giants — Arcturus in Bootes (34 light-years from the Sun), Pollux in Gemini (35 light-years from the Sun), and Capella (43 light-years from the Sun).

Because of their proximity, these giants give us a ringside seat for viewing the advanced stages of a star's life. Capella is of particular interest because astronomers in recent years have made precise observations that pin down Capella's exact state of evolution. And Capella is especially useful for another reason: It's a double star.

Unlike other nearby giants, Capella actually consists of two giant stars that revolve around each other. Because each star feels the other's gravity, astronomers can determine the mass of both stars. Learning their mass is an important step in understanding these stars because mass is the key determinant of a star's life, evolution, and eventual death.

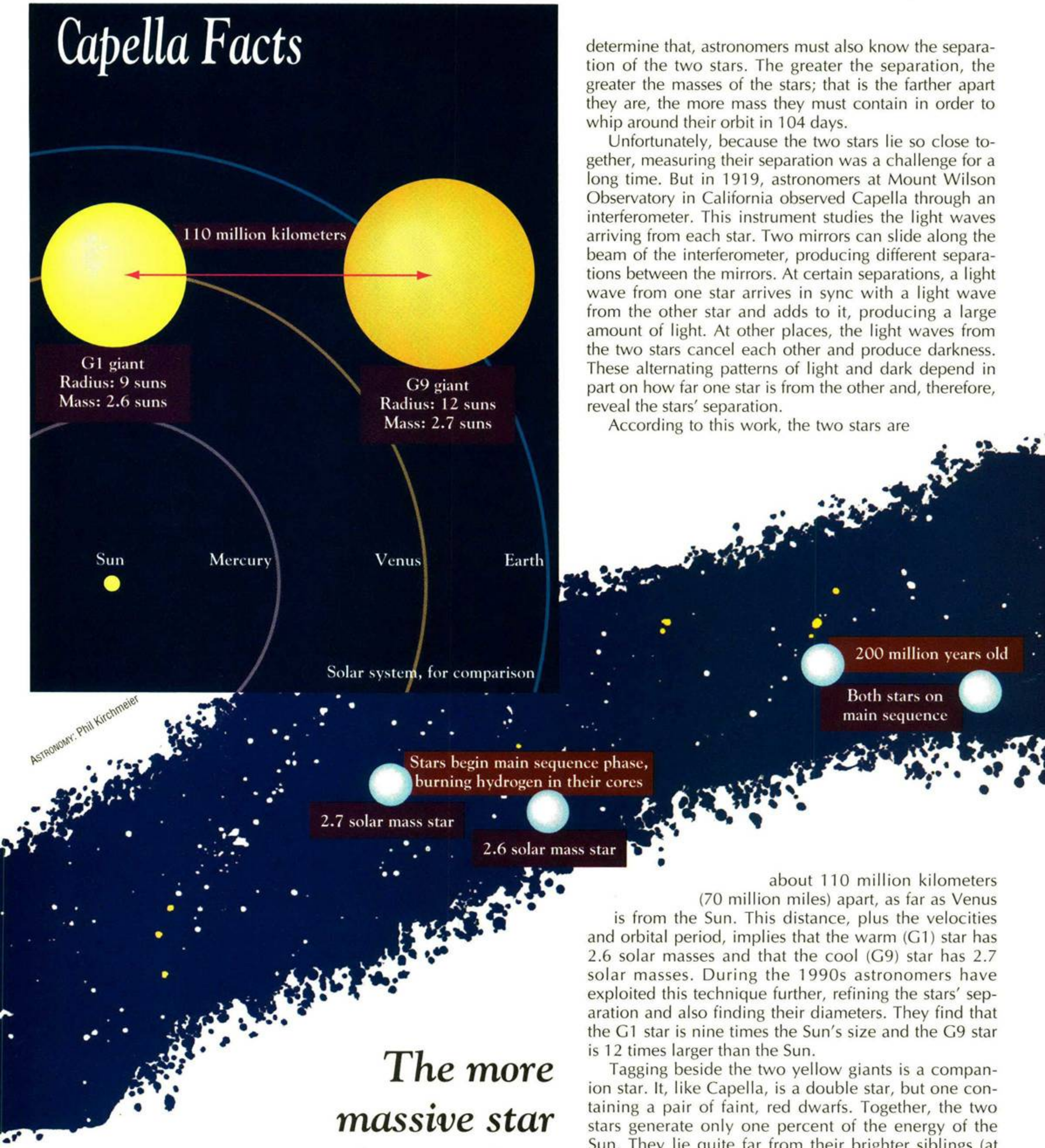
Capella's two stars lie so close together that no ordinary telescope has ever split the pair. Nevertheless, astronomers first discovered the star's double nature nearly a century ago. Astronomers at Lick Observatory in California were recording spectra of stars in order to determine their velocities toward or away from Earth. If a star moves toward us, its light waves get compressed and dark lines in its spectrum shift to shorter, or bluer, wavelengths. If a star moves away from us, its light waves get stretched and the spectral lines shift to longer, or redder, wavelengths.

In August 1899, after recording several spectra of Capella, Lick astronomer William Campbell noticed that these spectral shifts varied from night to night, which indicated that the star's velocity was changing. Campbell correctly concluded that another star was tugging on the main one. A few spectral lines from this second star even appeared in the spectra, confirming that Capella was indeed a double star. The spectral shifts repeat every 104 days, so the two stars revolve around each other this often.

As astronomers now know, both stars are of spectral type G but they have slightly different temperatures. The warmer (type G1) has a temperature of 5700 kelvins, and the cooler (type G9) has a temperature of 4900 K. For comparison, the Sun (a type G2) has a temperature of 5770 K. Because each Capella star is a giant, each emits much more light than the Sun does. The G1 star emits about 75 times more light than the Sun, and the G9 star emits slightly less, about 65 suns.

Both stars also have similar masses, with the cooler, G9 star being slightly more massive. Astronomers deduce the similarity in mass from the orbital velocities of the stars. Consider Earth and the Moon: The Moon moves quickly in its orbit but Earth moves little in response because it is far more massive. In the case of Capella, the spectral shifts reveal that both stars move in their orbits at similar speeds, indicating that they have similar masses.

Knowing the ratio of the masses, however, does not reveal just how much mass each star has. In order to


Capella Facts
110 million kilometers
G1 giant
Radius: 9 suns
Mass: 2.6 suns
G9 giant
Radius: 12 suns
Mass: 2.7 suns
Sun
Mercury
Venus
Earth
Solar system, for comparison
200 million years old
Both stars on main sequence
Stars begin main sequence phase, burning hydrogen in their cores
2.7 solar mass star
2.6 solar mass star

ASTRONOMY: Phil Kirchmeier

determine that, astronomers must also know the separation of the two stars. The greater the separation, the greater the masses of the stars; that is the farther apart they are, the more mass they must contain in order to whip around their orbit in 104 days.

Unfortunately, because the two stars lie so close together, measuring their separation was a challenge for a long time. But in 1919, astronomers at Mount Wilson Observatory in California observed Capella through an interferometer. This instrument studies the light waves arriving from each star. Two mirrors can slide along the beam of the interferometer, producing different separations between the mirrors. At certain separations, a light wave from one star arrives in sync with a light wave from the other star and adds to it, producing a large amount of light. At other places, the light waves from the two stars cancel each other and produce darkness. These alternating patterns of light and dark depend in part on how far one star is from the other and, therefore, reveal the stars' separation.

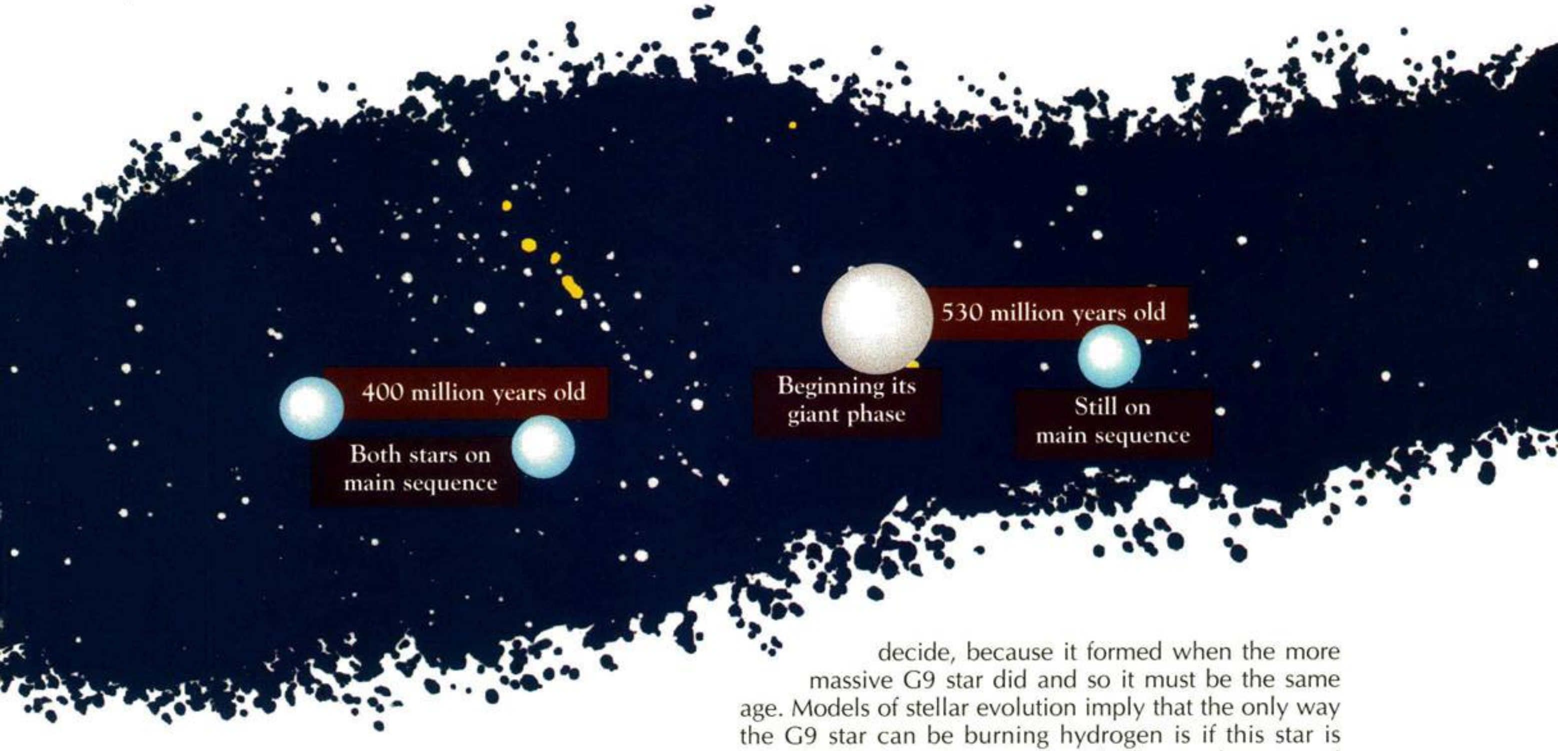
According to this work, the two stars are about 110 million kilometers (70 million miles) apart, as far as Venus is from the Sun. This distance, plus the velocities and orbital period, implies that the warm (G1) star has 2.6 solar masses and that the cool (G9) star has 2.7 solar masses. During the 1990s astronomers have exploited this technique further, refining the stars' separation and also finding their diameters. They find that the G1 star is nine times the Sun's size and the G9 star is 12 times larger than the Sun.

Tagging beside the two yellow giants is a companion star. It, like Capella, is a double star, but one containing a pair of faint, red dwarfs. Together, the two stars generate only one percent of the energy of the Sun. They lie quite far from their brighter siblings (at least 0.15 light-year or about 1.4 trillion kilometers). But astronomers suspect the red stars are linked to the yellow ones because the stars have similar distances from Earth and similar motions through space. If so, Capella is really a *quadruple* system, consisting of four separate stars — two big and bright ones, and two small and faint ones.

*The more massive star exhausted its hydrogen first and started to expand.*

The two red dwarfs are at the beginning of the main sequence phase of their life cycles and will remain unchanged for billions of years. But the yellow giants of Capella are moving through a quickly changing part of their life cycles as they near their ends. The new data on these stars have helped astronomers pin down just where these stars are in their evolution.

Both stars were once on the main sequence, as the Sun now is, fusing hydrogen into helium at their cores. Because the stars are more massive than the Sun, they were hotter and bluer. In fact, while on the main sequence, both stars probably resembled the blue-white B-type star Regulus in the constellation Leo.



*After* a star exhausts the hydrogen at its core, it leaves the main sequence. The core is now full of helium, so the star begins to burn hydrogen in a layer surrounding the core in order to provide the energy the star radiates away at its surface. The new source of energy causes the star to expand and cool, making a star like Capella turn white and then yellow. As the star expands and cools further, it brightens and becomes orange.

As the outer layers expand, the core contracts and gets so hot that the helium in it begins to burn, fusing into carbon and oxygen. The rapid onset of helium burning causes an abrupt change in the star's brightness and color. The star's core expands, but its energy output drops. This causes the outer layers to simultaneously shrink and heat up. So the star becomes yellow again, and also smaller and fainter than it had been when it was an orange giant.

Where do the stars of Capella fit into this evolutionary sequence? Astronomers agree that the less massive star — that is, the warm G1 star — is in an early phase of giant evolution, having just left the main sequence. It is burning hydrogen in a layer surrounding its core and has not yet started to burn helium.

More uncertain is the status of the cooler G9 star, which has slightly more mass than its mate. Since a more massive star evolves faster, it must be in a more evolved state. The question for astronomers is, Has the G9 star just become a yellow giant for the first time, so that like the other star it is burning only hydrogen? Or has the star already gone through the orange giant phase and begun to burn helium?

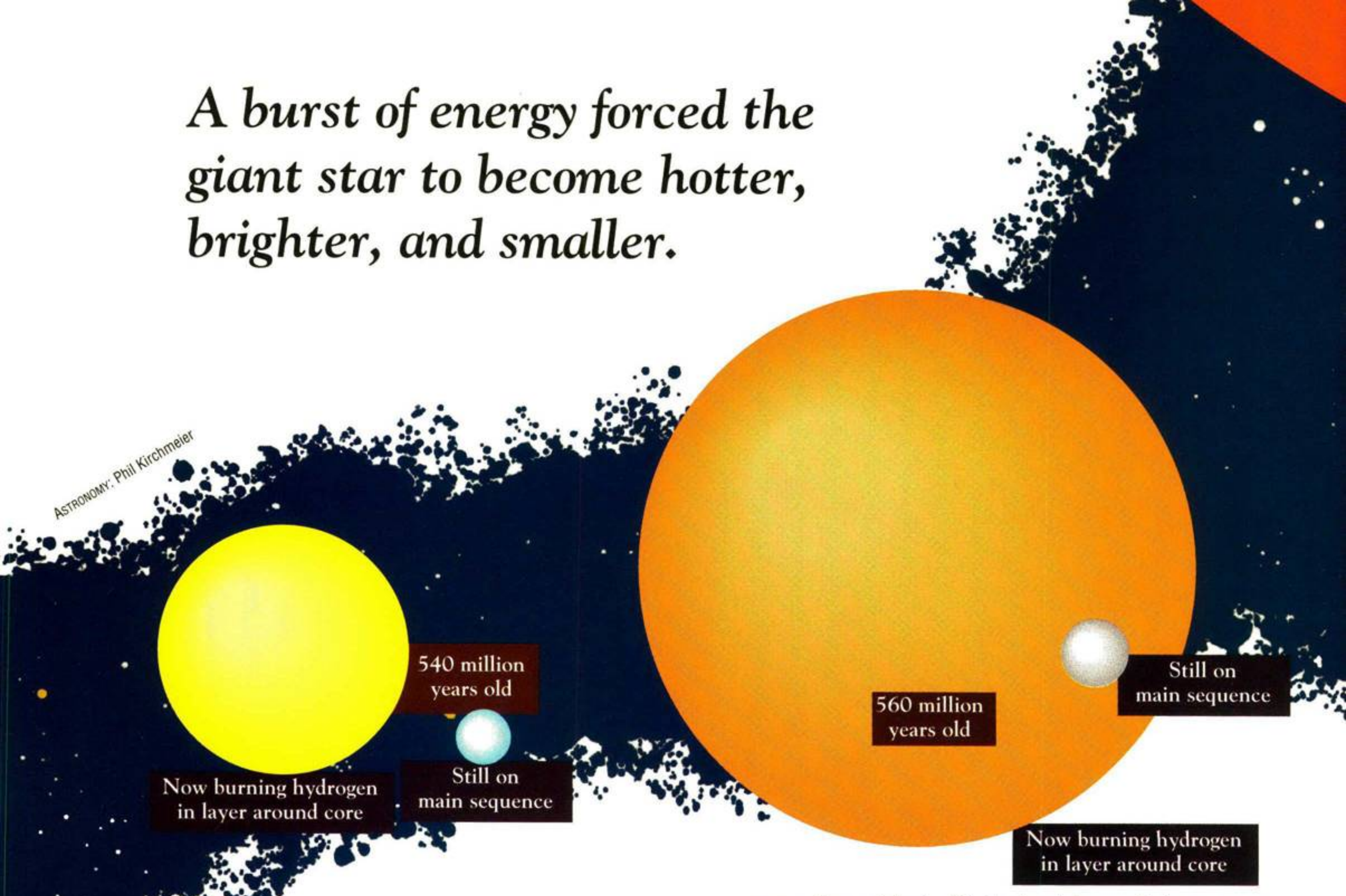
Recent observations suggest that the second possibility is the truth. The G1 star helps astronomers decide, because it formed when the more massive G9 star did and so it must be the same age. Models of stellar evolution imply that the only way the G9 star can be burning hydrogen is if this star is younger than its mate. Because both stars have equal ages, the models indicate the cool G9 star must have evolved to the point where it ignited its helium.

In 1991 Danish astronomer Johannes Andersen and his colleagues argued this case. Andersen's team noted that the orbits of the two Capella giants around each other are circular, whereas most binaries with similar periods have highly elliptical orbits. This suggests that Capella's orbit was once elliptical but has become circular.

Such circularizing of the orbit results from the gravitational force that each star exerts on the other. The rate of circularization depends in part on how close one star is to the other. The closer the stars are, the faster their orbits become circular. Although ordinary telescopes cannot split the pair, the stars of Capella are nevertheless 110 million kilometers apart. This is so far that circularization would take longer than the Galaxy is old, if the stars were always as they are now.

But the rate of circularization also depends on the size of the stars: The bigger they are, the faster the rate. In fact, the circularization rate varies as the eighth power of the star's diameter; that is, it goes 256 times faster for a star twice as large as another. If the cooler star of Capella had once been an orange giant several times larger than it is now, then in only a few million

*A burst of energy forced the giant star to become hotter, brighter, and smaller.*



ASTRONOMY: Phil Kirchmeier

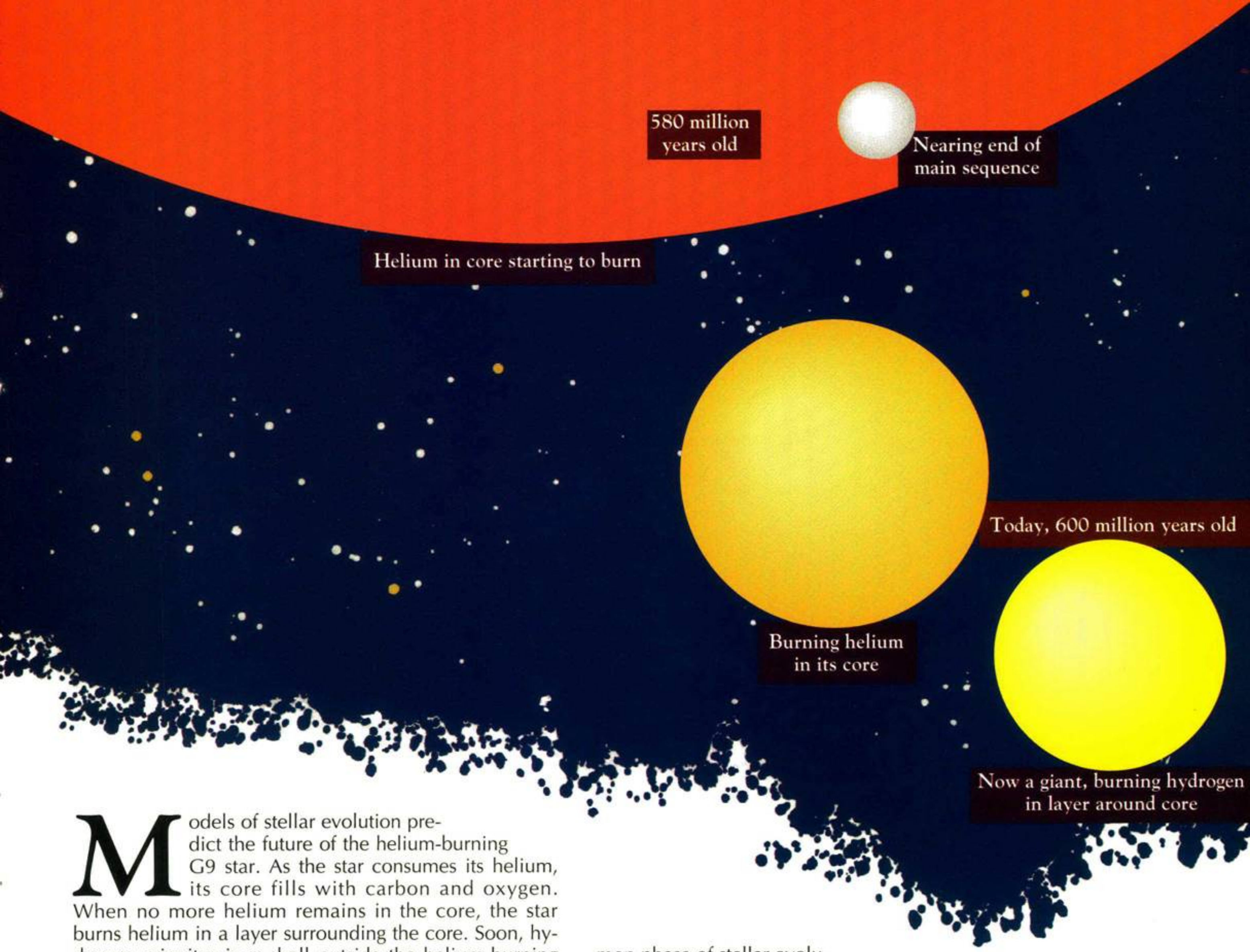
years the original elliptical orbit would have transformed into the circular one that astronomers see today. Thus, the star now must be in a later stage of evolution, burning helium in its core.

In 1992 astronomers reported additional evidence in favor of an advanced evolutionary stage for the G9 star. Catherine Pilachowski of Kitt Peak National Observatory in Tucson, Arizona, and James Sowell of the Georgia Institute of Technology in Atlanta measured the amount of lithium in the two Capella giants. Lithium provides a probe of a star's evolution because the element is fragile and burns up at even modest temperatures. Lithium can survive at a star's surface, which is relatively cool, but gets destroyed if it is dragged into the star's hot interior. When a yellow giant expands into an orange giant prior to helium ignition, the surface layers of the star get churned up and pulled inside, where the lithium is destroyed.

Pilachowski and Sowell found that the warmer G1 star has a normal amount of lithium, similar to the amount it was probably born with. This confirms that the star has only recently become a giant. But the cooler G9 star has 160 times less lithium than its mate. This suggests that the G9 star was once a larger orange giant and that during this stage destroyed most of its lithium. Today, the star is a hotter but smaller object that burns helium at its core.

**CAPELLA MAY HAVE FLED** from the nearby star cluster in Taurus called the Hyades (bottom right). Or Capella (far left) might have formed in a giant cloud that bred both the star and the Hyades.

Randall Wehler


580 million years old
Nearing end of main sequence
Helium in core starting to burn
Today, 600 million years old
Burning helium in its core
Now a giant, burning hydrogen in layer around core

Models of stellar evolution predict the future of the helium-burning G9 star. As the star consumes its helium, its core fills with carbon and oxygen. When no more helium remains in the core, the star burns helium in a layer surrounding the core. Soon, hydrogen reignites in a shell outside the helium-burning layer, so that the star burns both hydrogen and helium.

During this stage, the giant again expands, making its surface cooler, redder, and brighter. The star first becomes an orange giant and then a red giant. At some point the star kicks off its outer atmosphere, exposing its hot carbon-oxygen core and forming a planetary nebula around itself. Once a mighty giant, the star is on its way to becoming a humble white dwarf the size of Earth.

The models of Capella's evolution also yield an estimate of the system's present age, because the rate of evolution depends on the stars' masses. Because astronomers know these masses, as well as the temperatures, luminosities, and states of evolution of the stars, they can calculate Capella's age, which comes out to about 600 million years.

That is an interesting number because it is also the age of the Hyades, the nearest star cluster to Earth. The Hyades are 150 light-years away and form the face of the Bull in Taurus, which lies next to Capella's home of Auriga. Furthermore, the motion of Capella through space matches that of the Hyades. Perhaps Capella once belonged to the Hyades and got kicked out. Or perhaps, 600 million years ago, a huge cloud of gas and dust in our part of the Galaxy gave birth to a horde of new stars, including the Hyades and Capella.

Capella gives astronomers great insight into the nature of giants, stars that are rare but represent a common phase of stellar evolution. Indeed, many of the bright stars in the night sky will someday become giants. One of the first will probably be the blue main-sequence star Regulus, which has about four times more mass than the Sun and so is more massive than the stars of Capella. Regulus will enter the giant stage in less than 100 million years.

Following Regulus into gianthood will be bright, white, A-type main-sequence stars that speckle the night sky, stars such as Sirius, Vega, Altair, and Fomalhaut. Each of these will, in its turn, run out of hydrogen in its core, expand into a giant, and shine forth even more brightly.

The same fate also awaits our Sun. Billions of years from now, after all those other stars have died, the Sun will exhaust the hydrogen at its core. It will expand, cool, and turn orange and then red, shining with far greater intensity than it ever has before. At that future date, perhaps the Sun, as Capella does now, will attract astronomers who seek to fully understand the advanced stages in the lives of the Galaxy's stars. ☐

---

*Ken Croswell is an astronomer and writer who lives in Berkeley, California. His first book,* The Alchemy of the Heavens: Searching for Meaning in the Milky Way, *will be published this May by Anchor Books.*

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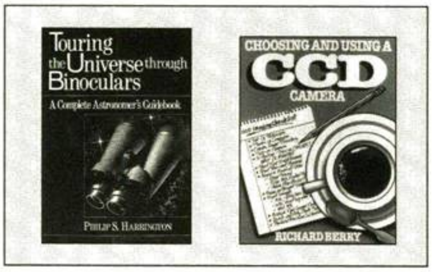
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# SKY ALMANAC

## Highlights
### by Rick Shaffer

| Date | Event |
|---|---|
| 2 | Ceres at Opposition . . . *(p. 62)* |
| 26 | Venus Joins Neptune . . . . . *(p. 62)* |

**all month:**

See the Elusive Zodiacal Light. *(p. 56)*

Mars at Its Best. . . . . . . . . *(p. 61)*

Spot Mars' Faint Moons . . . . . . *(p. 61)*

**First Views:**

Explore a Bright Winter Cluster . . . . . . *(p. 64)*

Comet Borrelly's Final Bow . . . . . . . . *(p. 64)*

**Observer's Challenge:**

Spy Hind's Variable Nebula . . . . . . *(p. 65)*

**The Starry Sky:**

Canis Minor . . *(p. 63)*

Mars rules the sky from dusk to dawn, shining brighter and appearing larger in the eyepiece than at any time in the past two years. The late winter sky also offers fine views of the bright asteroid Ceres and the faint zodiacal light.

**By Deborah Byrd**

As darkness falls on these chilly February evenings, a bright, steady light ascends in the eastern sky. This red intruder among the stars of the constellation Leo is **Mars**, the world next outward from Earth in orbit. We pass between Mars and the Sun on the night of February 11/12. As we do so, Mars appears opposite the Sun in our sky, a configuration called opposition, and shines unmistakably at magnitude –1.2.

Near its time of opposition, Mars rises around sunset and wheels across the sky all night. It stands highest in what Robert Frost called "the lunar noon," in other words, at midnight. Because the Moon also lies opposite the Sun when it appears Full to us, Mars can be found near this month's Full Moon on the night of February 14/15. The other bright object near Mars is 1st-magnitude Regulus, Leo's brightest star. At opposition the orange-red planet lies 8° northwest of the white star.

The best time to observe any outer planet is around the time of opposition, and Mars is no exception. At opposition Mars not only remains visible all night, but also shines brighter (at magnitude –1.2) and appears larger in a telescope (at 13.9" in diameter) than at any time in the past two years. Its brightness means that Mars outshines every star except for glittering Sirius, the –1.5-magnitude luminary of Canis Major. Its size means the often subtle markings on the planet's surface will be easier to see in a telescope. The bright white north polar cap stands out prominently even on nights of relatively poor seeing. The intriguing dark markings, which change as the Martian winds blow and desert sands shift, are the features to hunt for when conditions are excellent.

Despite Mars' prominence this winter, veteran observers of the Red Planet may notice that the planet appears dimmer and smaller than it has at recent oppositions. Indeed, this is Mars' most distant opposition in many years. Because the planets don't orbit the Sun in perfect circles, the distance between Mars and Earth at opposition varies depending on where they lie in their orbits. Mars had a very close opposition in 1988, when its perihelion, or closest point to the Sun, came at about the same time Earth

## See the Elusive Zodiacal Light

John Cordiale

February and March are the best times for evening skywatchers to view a subtle but beautiful phenomenon, the zodiacal light. From a dark-sky observing site, you can see the zodiacal light in the western sky after the glow of twilight has faded completely. Because the zodiacal light glows so subtly, the Moon's light can easily drown it out, so be sure to search before the Moon returns to the evening sky. That means the best time to see it in February begins around the 17th and runs to the end of the month.

Look for a broad glow shaped like a cone that comes up from the western horizon and tilts toward the south. The base of the cone extends about 20° to 30° *along the horizon* and the long sides of the cone continue along the ecliptic for about three times that, although you'll need exquisite conditions to follow the glow for a full 90°.

The zodiacal light results from sunlight scattering off dust particles lying in the plane of the ecliptic. It appears dim because our eyes intercept only a tiny fraction of this scattered light. It is easiest to see in the evening sky in late winter and early spring because the ecliptic then makes a steep angle with the western horizon after sunset.

# FEBRUARY

**2** The Moon passes 6° north of Saturn, 3 a.m. EST
Asteroid Ceres is at opposition (p. 62)

**3** Mercury is in inferior conjunction, 6 p.m. EST

**7** First Quarter Moon is at 7:54 a.m. EST

**8** The Moon is at apogee (251,294 miles from Earth), 1:02 p.m. EST

**11** Mars is closest to Earth (62.8 million miles away), 9 a.m. EST
Mars is at opposition, 10 p.m. EST (p. 61)

**15** The Moon passes 10° south of Mars, 5 a.m. EST
Full Moon is at 7:15 a.m. EST

**19** The Moon passes 0.9° north of Spica, noon EST

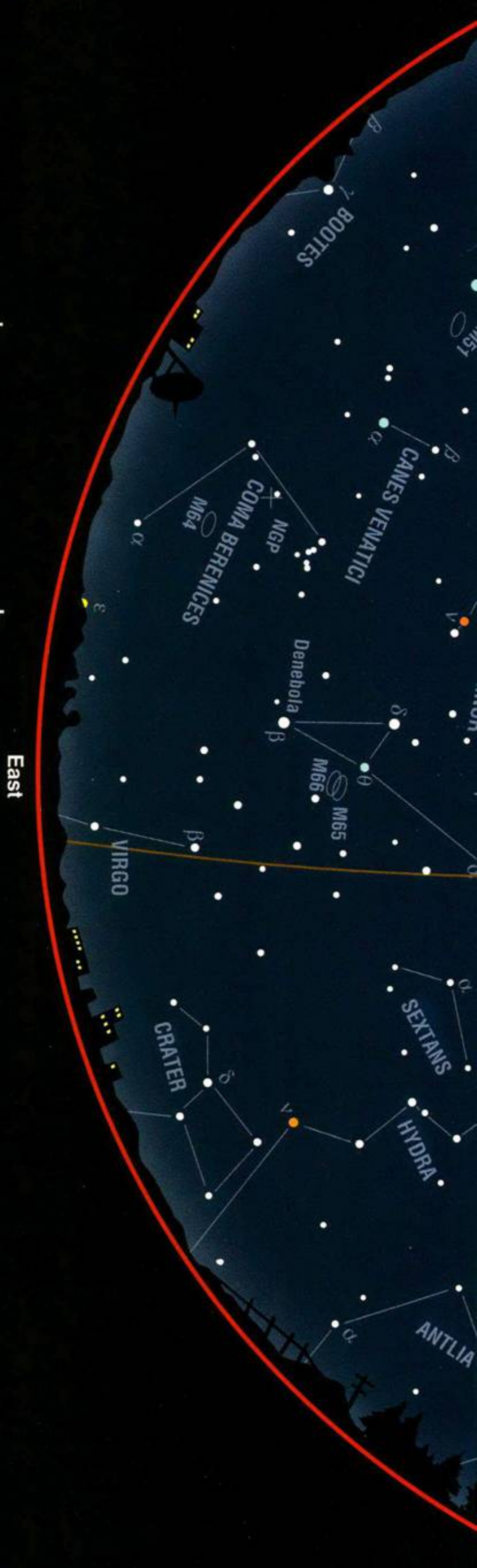
**22** Last Quarter Moon is at 8:04 a.m. EST
The Moon is at perigee (230,020 miles from Earth), 9:11 p.m. EST
The Moon passes 2° north of Jupiter, midnight EST

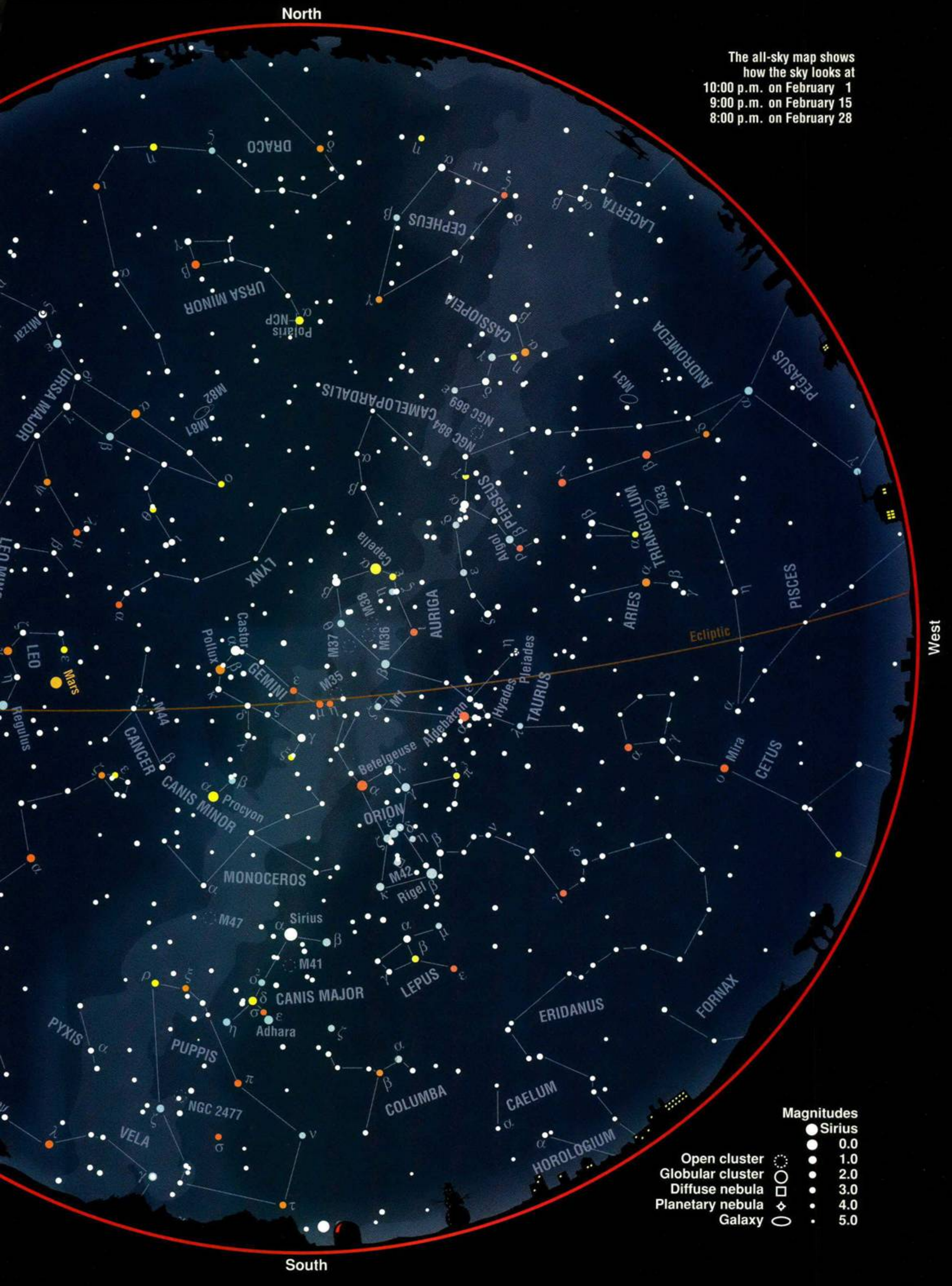
**25** The Moon passes 4° north of Neptune, midnight EST
The Moon passes 4° north of Venus, midnight EST

**26** Venus passes 0.7° north of Neptune, 5 a.m. EST (p. 62)
The Moon passes 6° north of Uranus, 8 a.m. EST

**27** The Moon passes 5° north of Mercury, 6 a.m. EST

| Sun. | Mon. | Tue. | Wed. | Thu. | Fri. | Sat. |
|---|---|---|---|---|---|---|
|  |  |  | 1 🌒 | 2 🌒 | 3 🌒 | 4 🌒 |
| 5 🌒 | 6 🌒 | 7 🌓 | 8 🌔 | 9 🌔 | 10 🌔 | 11 🌔 |
| 12 🌕 | 13 🌕 | 14 🌕 | 15 🌕 | 16 🌕 | 17 🌕 | 18 🌕 |
| 19 🌖 | 20 🌖 | 21 🌖 | 22 🌗 | 23 🌘 | 24 🌘 | 25 🌘 |
| 26 🌘 | 27 🌘 | 28 🌘 |  |  |  |  |

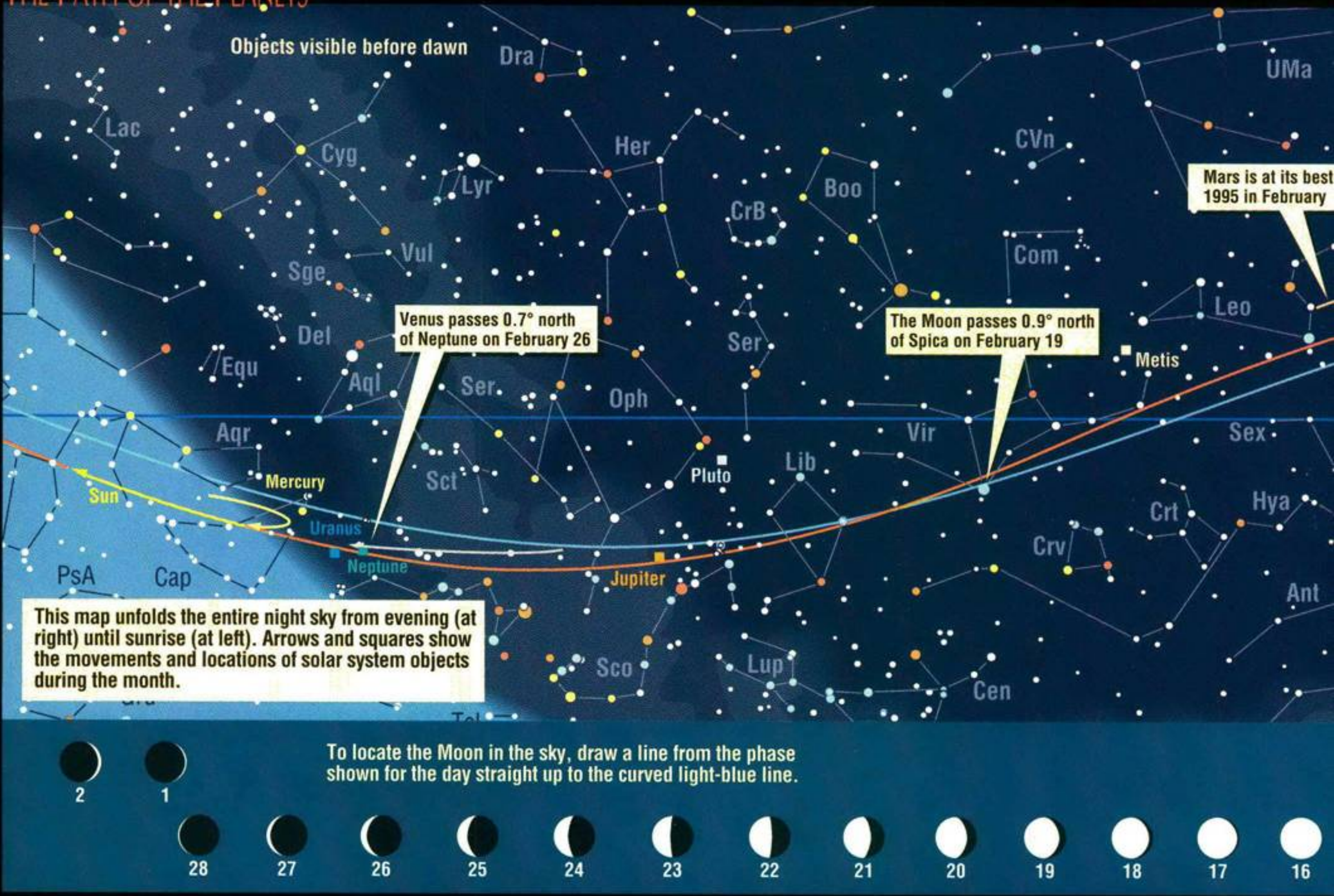

East
BOOTES
CANES VENATICI
COMA BERENICES
NGP
M64
Denebola
M66
M65
VIRGO
SEXTANS
CRATER
HYDRA
ANTLIA



The all-sky map shows
how the sky looks at
10:00 p.m. on February 1
9:00 p.m. on February 15
8:00 p.m. on February 28

North
South
West
DRACO
URSA MINOR
Polaris
NCP
CEPHEUS
LACERTA
CASSIOPEIA
ANDROMEDA
PEGASUS
M31
CAMELOPARDALIS
NGC 869
NGC 884
URSA MAJOR
Mizar
M81
M82
PERSEUS
Algol
TRIANGULUM
M33
ARIES
PISCES
LYNX
Capella
AURIGA
M38
M36
M37
Castor
Pollux
GEMINI
M35
M1
LEO
Mars
Regulus
M44
CANCER
Pleiades
Hyades
TAURUS
Aldebaran
Ecliptic
Mira
CETUS
Betelgeuse
CANIS MINOR
Procyon
ORION
M42
Rigel
MONOCEROS
M47
Sirius
M41
LEPUS
CANIS MAJOR
Adhara
ERIDANUS
FORNAX
PYXIS
PUPPIS
NGC 2477
VELA
COLUMBA
CAELUM
HOROLOGIUM
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

# THE PATH OF THE PLANETS


Dra
UMa
Lac
Cyg
Lyr
Her
CVn
Boo
CrB
Vul
Sge
Com
Leo
Del
Ser
Metis
Equ
Aql
Ser
Oph
Vir
Sex
Aqr
Lib
Mercury
Pluto
Sct
Sun
Hya
Crt
Uranus
Crv
Neptune
PsA
Cap
Jupiter
Ant
Sco
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Cen
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1
28
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26
25
24
23
22
21
20
19
18
17
16

Objects visible before dawn

Venus passes 0.7° north of Neptune on February 26

The Moon passes 0.9° north of Spica on February 19

Mars is at its best
1995 in February

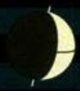
This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

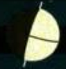
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

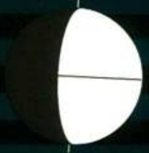
10"

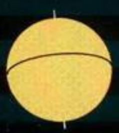
S
W — E
N

| PLANETS | MERCURY | MERCURY | VENUS | MARS |
|---|---|---|---|---|
| Date | February 15 | February 28 | February 15 | February 15 |
| Magnitude | 1.0 | 0.1 | –4.2 | –1.2 |
| Angular Size | 9.2" | 7.2" | 18.2" | 13.8" |
| Illumination | 25% | 55% | 65% | 100% |
| Distance (AU) from Earth | 0.729 | 0.931 | 0.918 | 0.677 |
| Distance (AU) from Sun | 0.395 | 0.452 | 0.722 | 1.662 |
| Right Ascension (2000.0) | 20h29.9m | 20h58.0m | 18h49.6m | 9h42.9m |
| Declination (2000.0) | –16°18' | –17°11' | –20°57' | 18°31' |



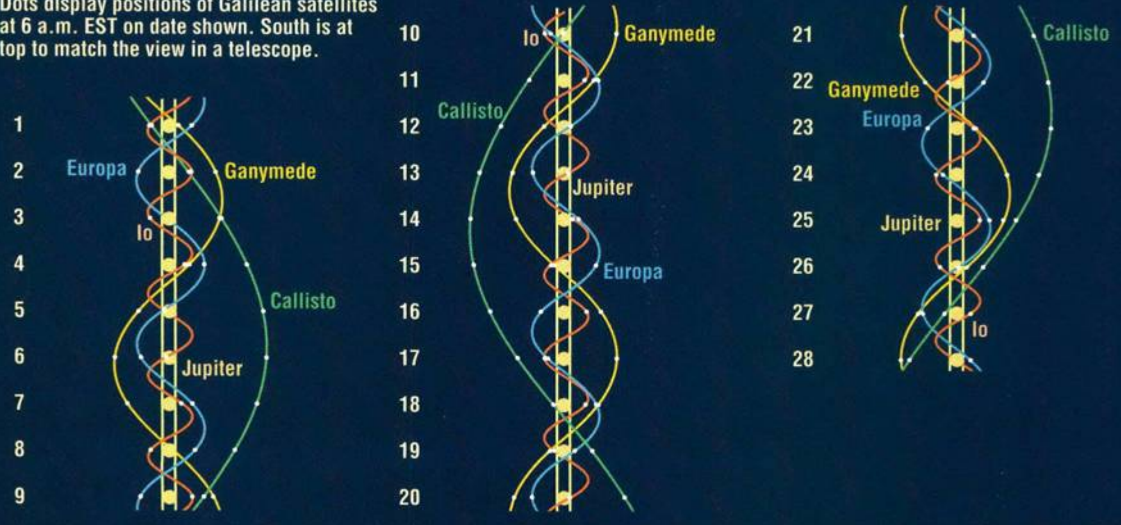


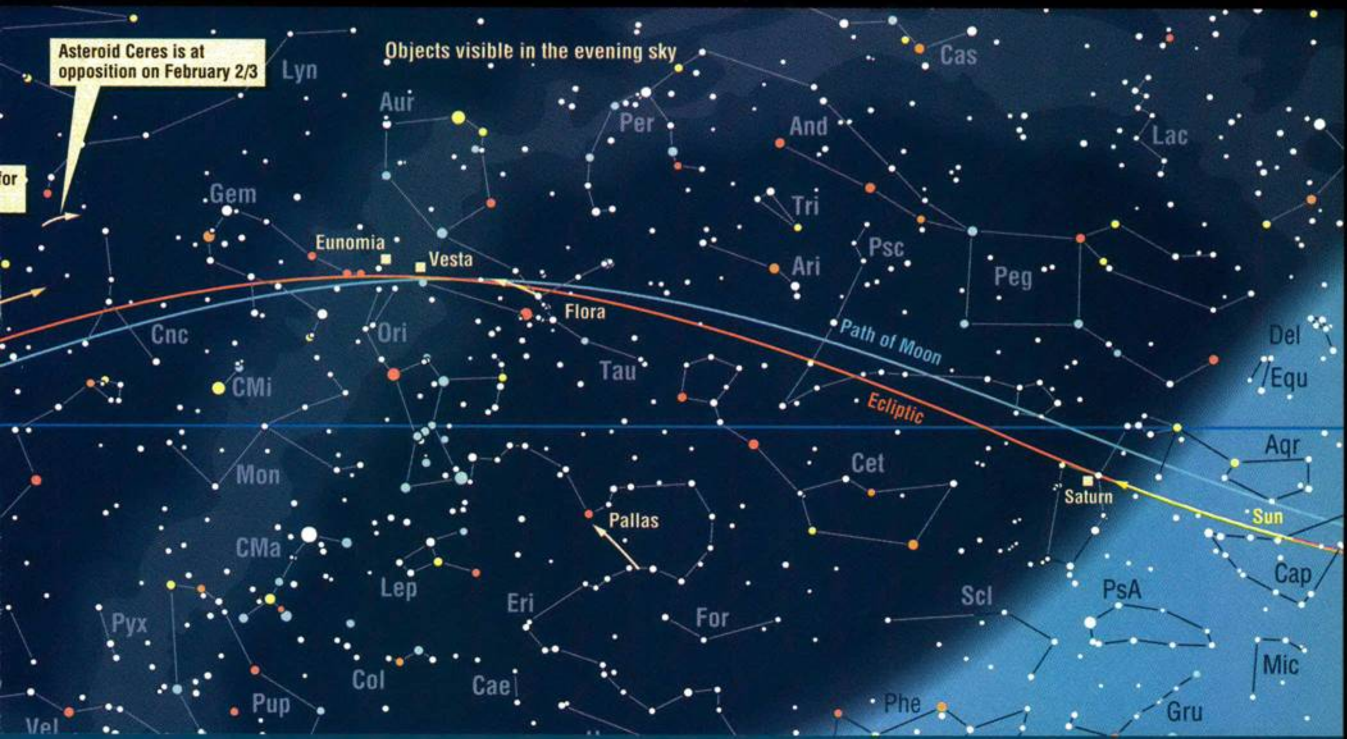




# JUPITER'S MOONS

Dots display positions of Galilean satellites at 6 a.m. EST on date shown. South is at top to match the view in a telescope.





Asteroid Ceres is at opposition on February 2/3
for
Objects visible in the evening sky
Lyn
Aur
Per
And
Cas
Lac
Gem
Tri
Eunomia
Vesta
Ari
Psc
Peg
Flora
Cnc
Ori
Tau
Path of Moon
Del
Equ
CMi
Ecliptic
Mon
Cet
Aqr
Saturn
Sun
Pallas
CMa
Cap
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Col
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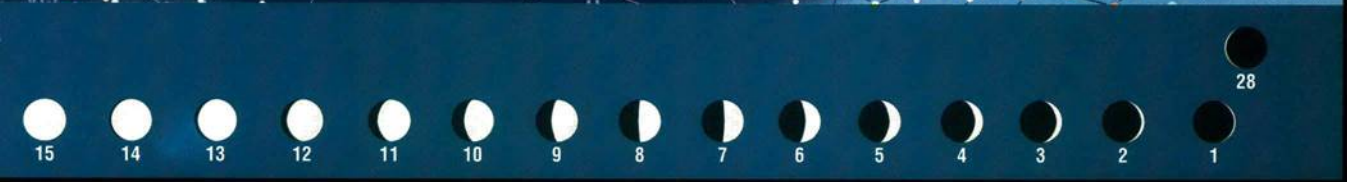
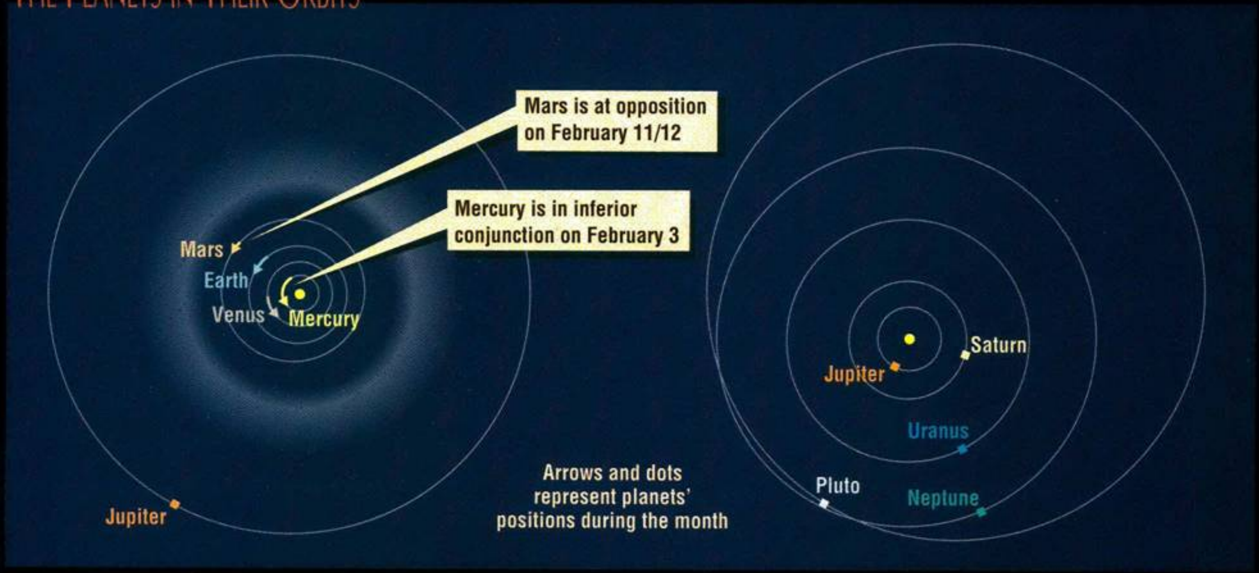


28
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

| JUPITER | SATURN | URANUS | NEPTUNE | PLUTO |
|---|---|---|---|---|
| February 15 | February 1 | February 15 | February 15 | February 15 |
| –2.0 | 1.0 | 5.9 | 8.0 | 13.7 |
| 35.4" | 15.7" | 3.4" | 2.2" | 0.1" |
| 99% | 100% | 100% | 100% | 100% |
| 5.565 | 10.519 | 20.567 | 31.009 | 29.883 |
| 5.369 | 9.673 | 19.698 | 30.173 | 29.821 |
| 16h44.1m | 22h53.1m | 20h01.4m | 19h44.4m | 16h05.0m |
| –21°30' | –9°01' | –21°02' | –20°43' | –6°59' |

# THE PLANETS IN THEIR ORBITS



Mars is at opposition on February 11/12
Mercury is in inferior conjunction on February 3
Mars
Earth
Venus
Mercury
Jupiter
Saturn
Jupiter
Uranus
Pluto
Neptune

Arrows and dots represent planets' positions during the month passed between Mars and the Sun. At that opposition, Mars lay only about 35 million miles from Earth and appeared exceedingly brilliant in our night sky.

This year, Mars will reach aphelion — its farthest point from the Sun — on March 14, and will lie nearly as far from the Sun as it can when we pass between it and the Sun. At opposition this year, the Red Planet shines from across more than 60 million miles.

Yet we on Earth still have something wonderful to think about at this opposition of Mars. In the past year, much progress has been made on the Pathfinder space mission to the Red Planet, which is scheduled for launch next year. In 1997, Pathfinder will become the first spacecraft to land on Mars in more than 20 years, coming to rest about 500 miles southeast of the location of the Viking 1 lander. Some researchers believe that if life ever got started on Mars, this is a likely spot, although the Pathfinder mission isn't designed to search for actual fossils of Martian algae or bacteria.

Thus in this year of Mars' opposition, new life is being breathed into the spaceborne exploration of the planet. When you see Mars burning like a pale flame in our night sky, think ahead to a time when a spacecraft from home may unearth evidence of early life on this desert world.

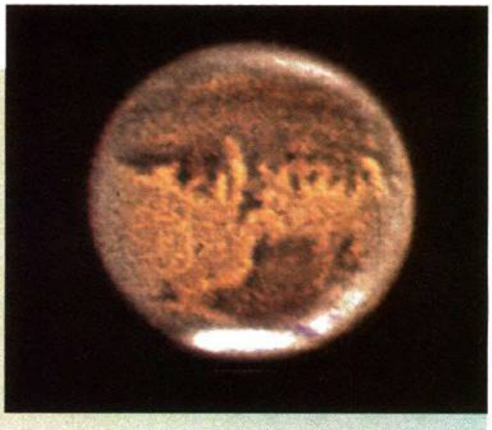
As Earth passes between the Sun and Mars, another outer planet falls so far behind us that it slips into the Sun's glare. In early February, look low in the west-southwest an hour after sunset for a final look at **Saturn**. The planet appears relatively inconspicuous at magnitude 1.0. The young crescent Moon aids in finding Saturn on the evening of February 1, when it passes just over 5° from the ringed planet. Saturn will pass behind the Sun in early March and afterward appear in the predawn sky. After the planet emerges into the morning sky, Earth will pass through

## Mars at Its Best

February finds Mars at opposition and at its best for 1995. The Red Planet remains bright and large throughout the month, but appears brightest and biggest when it is opposite the Sun in our sky on the night of February 11/12. It then shines at magnitude –1.2 and presents a disk measuring 13.9" across.

When you first view Mars at relatively low power, the north polar cap jumps out. The cap, a combination of water ice and carbon dioxide ice, appears as a bright white patch on the northern tip of the otherwise ocher-colored planet.

The other major type of feature you should see are the dark markings. These are areas of bare rock that have not been covered by the constantly shifting orange-red sands of Mars. To punch up the contrast of your view, try using an orange filter (Wratten #21) or a red filter (Wratten #23A). The dark areas will appear darker than without the filter, allowing you to see more detail. For more details on observing Mars during this apparition, see "Discover the Red Planet" (January 1995).

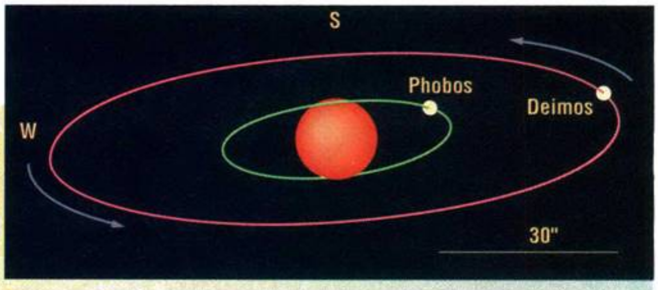


Don Parker

**MARTIAN CENTRAL MERIDIANS**

| Date | Central Meridian |
|---|---|
| February 1 | 217° |
| February 4 | 191° |
| February 7 | 165° |
| February 10 | 138° |
| February 13 | 112° |
| February 16 | 86° |
| February 19 | 60° |
| February 22 | 34° |
| February 25 | 8° |
| February 28 | 341° |

## Spot Mars' Faint Moons



**SATELLITE ELONGATIONS**

**Deimos**

| | |
|---|---|
| Feb. 8 | 10:24 a.m. |
| Feb. 9 | 4:42 p.m. |
| Feb. 10 | 10:54 p.m. |
| Feb. 12 | 5:12 a.m. |
| Feb. 13 | 11:24 a.m. |
| Feb. 14 | 5:42 p.m. |
| Feb. 15 | midnight |

**Phobos**

| | |
|---|---|
| Feb. 8 | 3:42 a.m., 11:22 a.m., 7:02 p.m. |
| Feb. 9 | 2:42 a.m., 10:20 a.m., 5:58 p.m. |
| Feb. 10 | 1:36 a.m., 9:16 a.m., 4:56 p.m. |
| Feb. 11 | 12:36 a.m., 8:14 a.m., 3:52 p.m., 11:30 p.m. |
| Feb. 12 | 7:10 a.m., 2:50 p.m., 10:30 p.m. |
| Feb. 13 | 6:10 a.m., 1:50 p.m., 9:30 p.m. |
| Feb. 14 | 5:08 a.m., 12:46 p.m., 8:24 p.m. |
| Feb. 15 | 4:04 a.m., 11:44 a.m., 7:24 p.m. |

Only a handful of observers have ever seen the two small satellites of Mars, Phobos and Deimos. In fact many consider this pair beyond the range of backyard scopes. But they have been glimpsed in scopes as small as 8 inches, and with Mars fairly close to Earth in February, now is a good time to hunt for these elusive bodies.

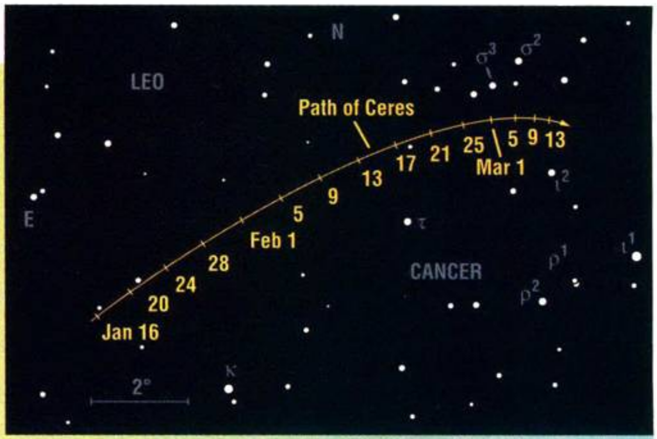
Although Phobos and Deimos are faint — at opposition on February 11/12, they glow at magnitudes 12.1 and 13.2, respectively — the chief problem comes from their extreme proximity to Mars' brilliant disk. At best, Phobos lies just 19" and Deimos 48" away from Mars. To have any hope of seeing the satellites, you need an excellent telescope with scrupulously clean optics. Then choose an eyepiece that provides sharp views all the way to the edge and place Mars just outside its field.

The best time to look for the satellites is when they lie as far from the planet as they get, either at eastern or western elongation. The table gives the eastern times of eastern elongation around opposition. To confirm a sighting, wait 10 to 20 minutes to see if you can detect the satellites' motion around Mars or Mars' motion against the background stars.

# Ceres at Opposition

The first asteroid ever discovered, 1 Ceres, reaches opposition on the night of February 2/3. The 7th-magnitude asteroid then will be just a bit too faint to be seen with the naked eye, but binoculars or a small telescope will bring it easily into view. When you do spot it, you will be gazing at the largest minor planet in the solar system, coming in at 1,000 kilometers in diameter.

Ceres begins February in far northeastern Leo, but by the 3rd crosses into northern Cancer, where it remains for the rest of the month. This is a relatively star-poor region of the sky, so you should have little trouble picking it out from the background stars. You can use the finder chart or table of coordinates (which show the asteroid's positions at 11 p.m. EST, 10 p.m. CST, 9 p.m. MST, and 8 p.m. PST) to locate Ceres in the weeks near its opposition.

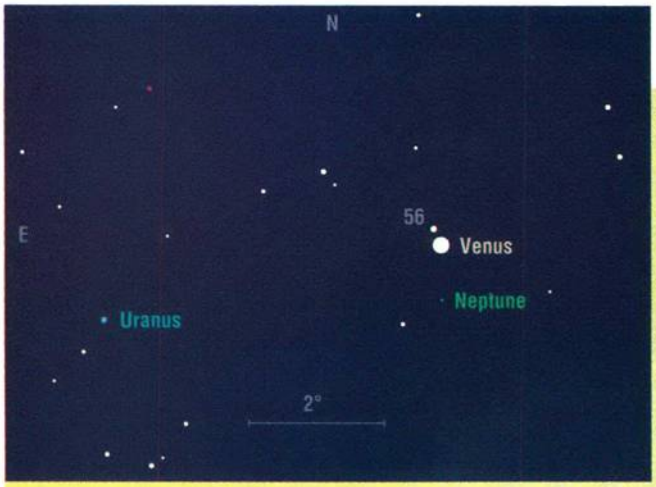


Kevin Bolam

**COORDINATES FOR CERES**

| Date | | R.A. (2000) | Dec. |
|---|---|---|---|
| January | 16 | 9h37.0m | 27°35' |
| January | 20 | 9h34.1m | 28°08' |
| January | 24 | 9h30.9m | 28°41' |
| January | 28 | 9h27.5m | 29°13' |
| February | 1 | 9h23.8m | 29°43' |
| February | 5 | 9h20.1m | 30°10' |
| February | 9 | 9h16.3m | 30°34' |
| February | 13 | 9h12.5m | 30°55' |
| February | 17 | 9h08.9m | 31°12' |
| February | 21 | 9h05.6m | 31°26' |
| February | 25 | 9h02.5m | 31°36' |
| March | 1 | 8h59.8m | 31°42' |
| March | 5 | 8h57.5m | 31°45' |
| March | 9 | 8h55.6m | 31°44' |
| March | 13 | 8h54.2m | 31°40' |

# Venus Joins Neptune



Step outside on any February morning, and Venus will draw your eye to the eastern sky. Shining at magnitude –4.2, it is by far the most brilliant starlike object in the predawn sky. It rises in a dark sky a little past 4 a.m. and remains unmistakable until the Sun comes up about two-and-a-half hours later.

Near the end of February, you can use the brightest planet as a guide to one of the faintest. On the morning of the 26th (left), with the waning crescent Moon shining nearby, Venus passes just 0.7° north of Neptune. (At the same time, Venus itself lies just 0.2° south of the 5th-magnitude star 56 Sagittarii.) You can see both planets in the same low-power field of view of a small telescope, but it won't be easy to pick out Neptune: At magnitude 8.0, it glows some 60,000 times fainter than Venus! You're better off placing Venus just outside the northern edge of the eyepiece's field of view, which will put Neptune near the center. You can easily identify Neptune by its blue-gray color.

If you're in the mood for exploring a little, point your scope 3° to the east of this pair. There you'll come across blue-green Uranus, glowing softly at magnitude 5.8. During the first two days of March, Venus will pass a mere 1.5° north of Uranus.

the plane of this planet's rings, and Saturn will for a time appear ringless.

While Saturn disappears from the evening sky in February, another celestial sight comes into view. After twilight fades away, start scanning the western sky for the legendary zodiacal light. If you're observing from a very dark site, you should see this softly radiant, rounded pyramid of light, which looks even "milkier" than the Milky Way.

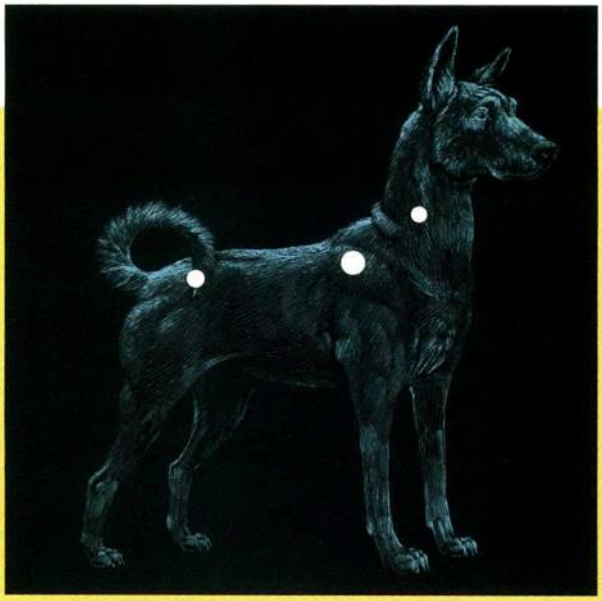
From the southern states or tropical latitudes — where the ecliptic always makes a steep angle to the horizon — the zodiacal light can be so noticeable that unknowing observers ask about it, wondering what it might be. It can be mistaken for the light of a city or town just beyond the horizon. Yet those who travel west on a dark road at night will find that the light always stays ahead of them, until the artificial light of a real city or town washes it from view.

The zodiacal light arises from sunlight reflecting off dust grains that move in the plane of the solar system. Thus the light follows the band of the ecliptic, the path of the Sun, Moon, and planets, across our sky. That's why Northern Hemisphere observers are most likely to see it in February and March: The ecliptic then makes a steep angle to the western horizon after sunset. Remember to look for it under dark country skies. It will appear once the last vestiges of twilight have faded away.

By midevening the zodiacal light has dipped below the horizon and Saturn has set, leaving Mars the lone planet in the sky until after midnight. **Pluto**, the next planet to rise, won't affect Mars' dominance, however, because it remains invisible to the naked eye. The diminutive planet lies in far western Ophiuchus and comes up around 1 a.m. It will climb higher in the sky and thus become easier to search for with a telescope as it approaches opposition in May.

While Pluto is faint, the next planet to appear is bright. While Pluto is invisible to the naked eye, this next planet is brighter than any star. It's **Jupiter**, rising around 2 a.m. and appearing well up in the southeast before dawn. And it appears a little higher in the predawn sky each day. Jupiter ranks as the second-brightest planet after Venus and shines this month at magnitude –2.0. It has joined Pluto in the nonzodiacal constellation Ophiuchus, the Serpent Bearer, though it lies well south and east of its neighbor. The telescopic view of Jupiter is always spectacular. This month the planet's disk measures 35.4" across.

## The Starry Sky: Canis Minor



Keith Ward

Ruddy Mars ascends in the east on these February evenings appearing brighter than it has for two years and outshining every star, save one. If you only shift your gaze westward a bit, you'll find the star that reigns supreme in brightness: the Dog Star Sirius in the constellation Canis Major (see last month's Starry Sky). If you're like me, and like stargazers throughout the centuries, you'll find it impossible to gaze at Sirius without at least glancing at its canine companion among the stars, Procyon in the constellation Canis Minor.

The ancient Greeks considered Canis Major and Canis Minor to be Orion's hunting dogs. Other skylore regarded them as belonging to Diana, goddess of the hunt, or to the woman of legendary beauty, Helen of Troy.

There's not much more to see in Canis Minor besides Procyon. The constellation consists basically of two noticeable stars, Procyon and a 3rd-magnitude star called Beta Canis Minoris, or Gomeisa. The second star is an optical double star, with its brighter component being a couple of hundred times more luminous than our Sun and located 140 light-years away.

Procyon is sometimes called the Little Dog Star. Even its proper name ties this star to Sirius. The Greek name is the equivalent of the Latin word *Antecanis,* meaning "before the dog." Procyon got this name because, at mid-northern latitudes, it rises shortly before Sirius and therefore heralds the arrival of the sky's brightest star. Early Arabian stargazers called Procyon Al Shi'ra al Shamiyyah or Siair Siami, both of which can be translated as "Northern Sirius."

Procyon seems always to be in Sirius' shadow, but it is a fascinating star in its own right. It ranks as the 8th-brightest star in the sky at magnitude 0.4 and the 6th-nearest of the naked-eye stars at 11 light-years away. It is a subgiant star, slightly more powerful than our own life-giving Sun, located in our sky at the edge of a softly luminous starlit band, the winter Milky Way.

Procyon is one of several stars in the night sky that caused the ancient notion of "the fixed stars" to evolve into our present-day concept of varied stellar distances and unceasing stellar motions. In 1718, Edmond Halley noted that Procyon, Sirius, and Arcturus were not located in the sky where star catalogs compiled by the ancient Greeks said they should be. Halley suggested that we can observe this shift in the positions of these moving stars over many centuries because the stars lie relatively close to Earth. This motion of nearby stars in relation to the positions of more distant stars is now called proper motion.

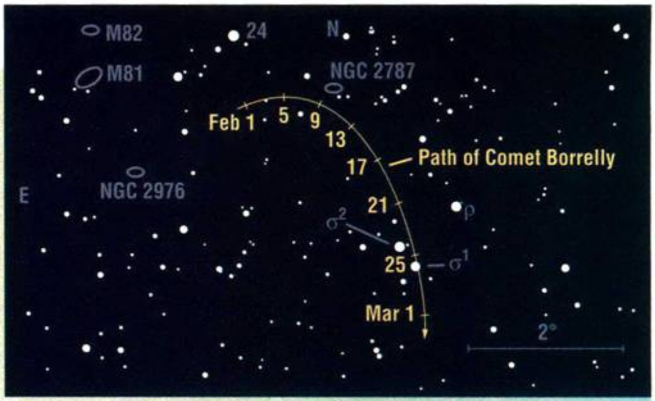
An interesting coincidence lies in the fact that Procyon, like Sirius, has a white dwarf companion. The companion was discovered in 1861 after astronomers observed the proper motion of Procyon over many decades. Procyon's motion relative to more distant stars does not trace a straight line across the sky; instead it follows a regular, wavelike path. The companion was later seen with the Lick Observatory 36-inch refractor, in 1896, almost exactly a century ago. — *Deborah Byrd*

# Comet Borrelly's Final Bow

Comet Borrelly has been a reasonably bright object in the night sky for the past six months. But that long run is now coming to a close. The comet is rushing away from both the Sun and Earth and, as it does so, it dims rapidly. At the beginning of February, Borrelly still glows respectably at magnitude 10.7, but by the end of the month it has faded by a factor of four, to magnitude 12.2.

Comet Borrelly spends the entire month in the northern part of Ursa Major, about 15° northwest of the famous Big Dipper. For Northern Hemisphere observers, that places the comet high in the sky for most of the long winter's night. It begins the month just 2° west of a pair of bright galaxies, M81 and M82. Glowing at magnitudes 6.9 and 8.4, respectively, both are considerably brighter than Borrelly, but don't let that fool you. Because galaxies and comets have similar fuzzy appearances when viewed through a small telescope, you must take care to determine which object is the comet.

The nicest stellar conjunction of February comes toward the end of the month, when the comet passes through a trio of 5th-magnitude stars: Rho ($\rho$), Sigma$^1$ ($\sigma^1$), and Sigma$^2$ ($\sigma^2$) Ursae Majoris. On the evening of the 26th, Borrelly passes just 1' west of $\sigma^1$ UMa. The finder chart and table of coordinates will help you locate the comet throughout the month. Positions are given for 11 p.m. EST (10 p.m. CST, 9 p.m. MST, and 8 p.m. PST).



**COORDINATES FOR COMET BORRELLY**

| Date | R.A. (2000) | Dec. |
|---|---|---|
| February 1 | 9h32.1m | 68°57' |
| February 5 | 9h26.6m | 69°04' |
| February 9 | 9h21.4m | 68°58' |
| February 13 | 9h16.9m | 68°42' |
| February 17 | 9h13.1m | 68°16' |
| February 21 | 9h10.3m | 67°43' |
| February 25 | 9h08.4m | 67°01' |
| March 1 | 9h07.4m | 66°14' |

## First Views:

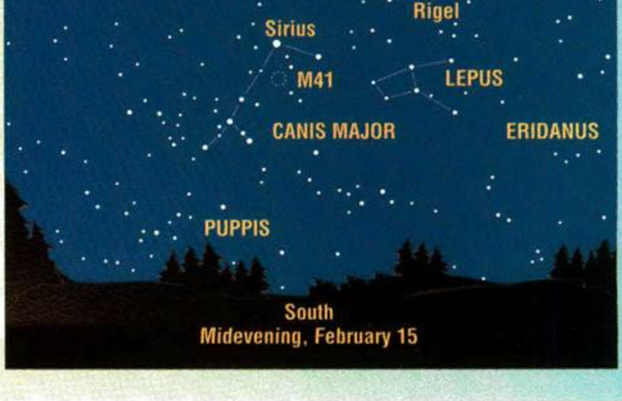
# Explore a Bright Winter Cluster

Luke Dodd

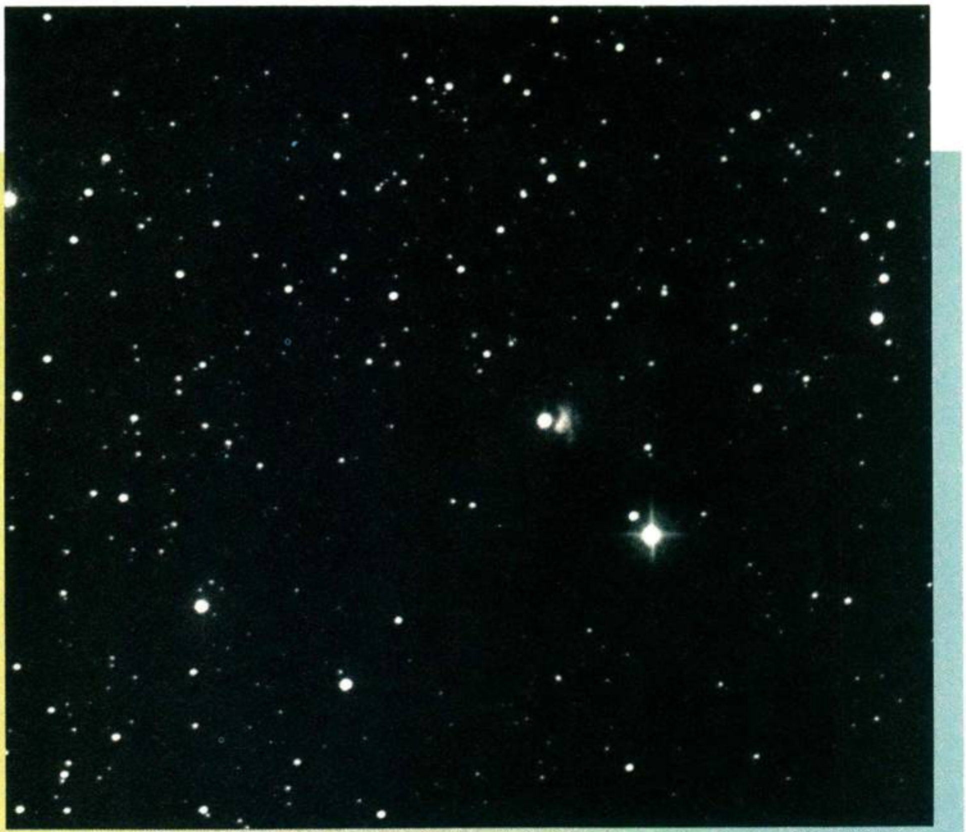
With the holiday excitement now over, it's time to break out that new telescope and take it out under the stars. After checking out the Moon and bright planets (every newcomer's introduction to the joys of skywatching), most budding observers set their sights beyond the solar system. For owners of small scopes, perhaps the best type of object to shoot for is a bright open star cluster because they appear most stunning at the low powers smaller scopes excel at.

Fortunately the winter sky abounds with pretty open clusters. One of the finest is M41 (NGC 2287) which, at magnitude 4.5, is bright enough to spot with the naked eye on a dark night. It lies in the constellation Canis Major, just 4° south of Sirius, the brightest star in the sky. Finding it is a breeze — simply point your finderscope at Sirius, then sweep slowly south, and you'll soon spy this tight grouping of bright stars.

M41 measures 38' across, making it larger than the Full Moon. The large size means that a low-power, wide-field eyepiece will provide the most satisfying view (high powers show only a portion of the cluster at any time). About 80 stars pack into M41, about half of them visible in a 4-inch telescope. Note M41's brightest member, a 7th-magnitude star with a distinct orange color located at the cluster's center. Four of the remaining dozen brightest stars also appear orange, while the others are an intense blue-white.



## Observer's Challenge: **Spy Hind's Variable Nebula**

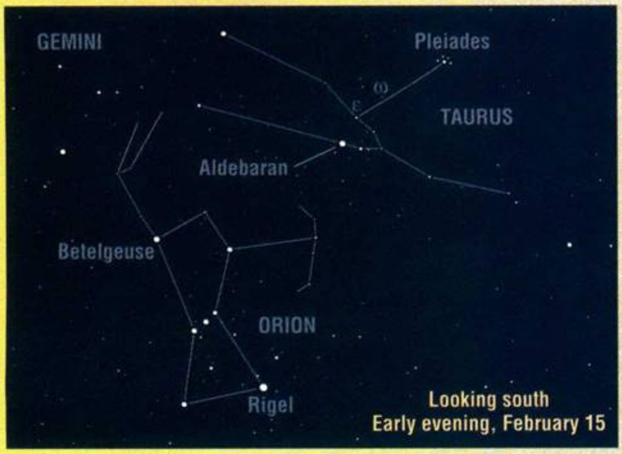


Martin C. Germano

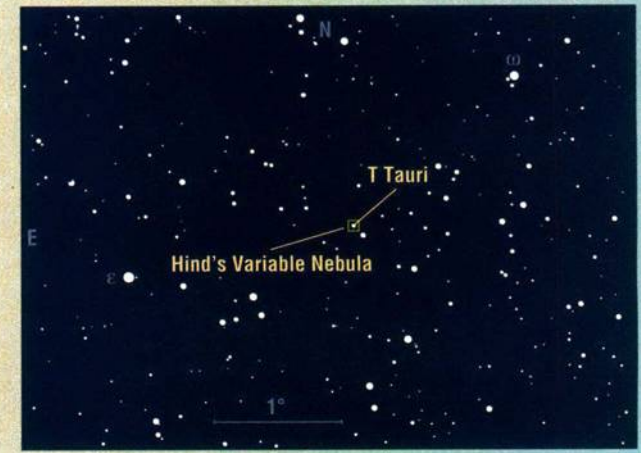
The winter sky is renowned for its many star-forming regions, but perhaps none is as intriguing as Hind's Variable Nebula (NGC 1554-5). This reflection nebula, an interstellar cloud of dust and gas that scatters light from a nearby star in our direction, lies just above the V-shaped grouping of stars that forms the face of Taurus, the Bull. As its name implies, Hind's Variable Nebula fluctuates in brightness. You will need at least a 10-inch telescope to detect this ghostly nebula, which appears as a small hazy patch only 30" across. Yet small scopes easily show the object responsible for the brightness changes, a variable star known as T Tauri.

This is not a true star, however. It is a protostar: A star-to-be that recently began nuclear reactions but hasn't yet settled down on the main sequence. T Tauri varies irregularly from about magnitude 9 to 13.5, though it rarely fades below magnitude 10.6.

You can find T Tauri by starhopping from either 4th-magnitude Epsilon (ε) or 5th-magnitude Omega (ω) Tauri. Or you can locate T Tauri with a good set of setting circles and a polar-aligned mount by centering your field of view 1 minute of right ascension west of Delta[1] ($\delta^1$) Tauri and slewing north in declination 2°. T Tauri is the more northern star of a pair that should be near the center of your field.



Looking south
Early evening, February 15



The brightest planet of all, **Venus**, comes up about two hours after Jupiter and lies about 15° below the giant planet as dawn begins to break. At magnitude –4.2, Venus appears even more dazzling than Jupiter. Telescopically, this planet appears gibbous, that is, more than half illuminated but less than full. Its disk measures 18.2" in diameter.

**Uranus** and **Neptune** emerge from the dawn around mid-February and sweep up behind Venus before the month ends. Venus passes 0.7° north of 8th-magnitude Neptune on February 26, when the waning crescent Moon also lies nearby. The conjunction of Venus and 6th-magnitude Uranus will come in early March.

The innermost planet, **Mercury**, passes between Earth and the Sun on February 3. It then moves into the predawn sky and will reach greatest elongation on March 1. This is not a favorable elongation of Mercury, however (at its best, the planet appears only 5° high 30 minutes before sunrise), and you will have difficulty seeing it. ☐

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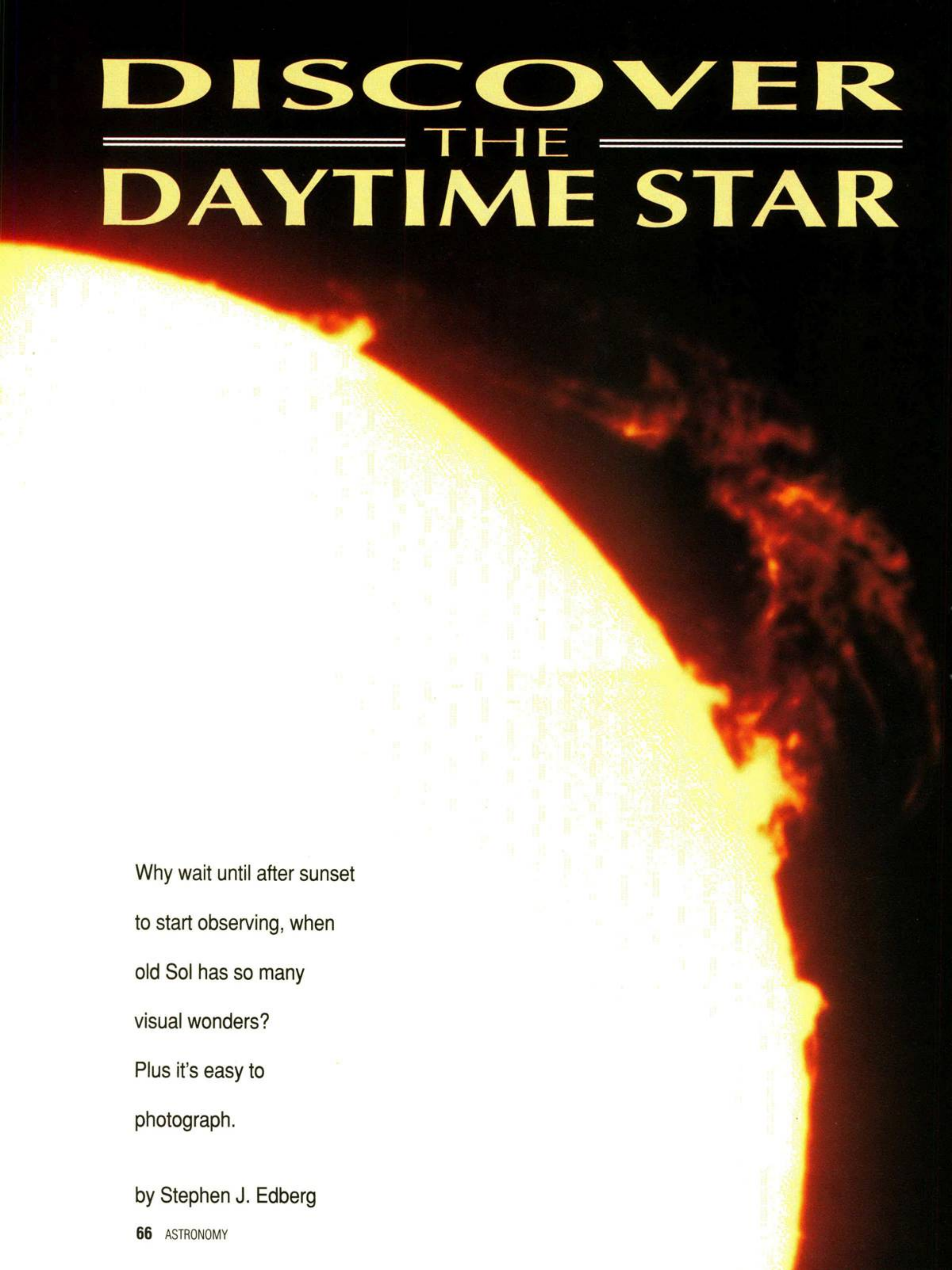
*Deborah Byrd writes and produces the daily "Earth and Sky" radio series. Rick Shaffer is an engineer and writer living in Southern California.*

# DISCOVER THE DAYTIME STAR



Why wait until after sunset to start observing, when old Sol has so many visual wonders? Plus it's easy to photograph.

by Stephen J. Edberg

To some the Sun sits in the sky like a yellow beach ball, just a barrier to lunar, planetary and deep-sky observing. But instead of considering it a hindrance, why not make it an observing target? With the proper equipment and techniques, the nearest star comes alive with thousands of minute features gleanable with eye or camera. Better yet, daytime observing doesn't require dark adaptation or red flashlights, nor do neighborhood streetlights pose a problem. That alone makes solar observing and photography more convenient; it's something to do during a lunch hour. In what follows, we will look at ways to observe the Sun and photograph it and then discuss what features to look for.

But first, a word of warning: Never directly observe the Sun without proper eye protection! Materials that look like they filter sunlight — sunglasses, smoked glass, or window tinting material — don't block harmful infrared radiation. Worse yet are filters that thread into eyepieces, the kind included with many inexpensive telescopes. The Sun's heat can shatter these filters and blind a hapless observer instantly. What is the safest way to look at the Sun? Commercially available solar filters that slide over the front of the telescope objective are safe and effective. Another observing technique, image projection, is cheaper than filters.

### Ready . . . Aim . . . Project

Before starting any solar observing session, cap the scope's finder so intensified sunlight won't burn wayward eyes or shirts that happen to get near its focus. In lieu of a finder, aim the telescope by making its shadow on the ground appear as small as possible; then slip in a low-power eyepiece.

Image projection doesn't require looking at the Sun directly. Instead, an eyepiece projects the image onto a screen, something as simple as a sheet of white paper. (Unless you've got steady hands, use a frame to hold the screen.) "Stopping down" (covering) a portion of the telescope aperture tones down image intensity. Sunglasses also reduce eyestrain caused by looking at a bright image.

Project the Sun with an inexpensive eyepiece, such as a Kellner, because solar heat can damage an expensive eyepiece's coatings or the cement that holds its components together. If you use binoculars, check with the manufacturer to be sure internal components won't outgas or melt in the intense heat collected by the objective lens.

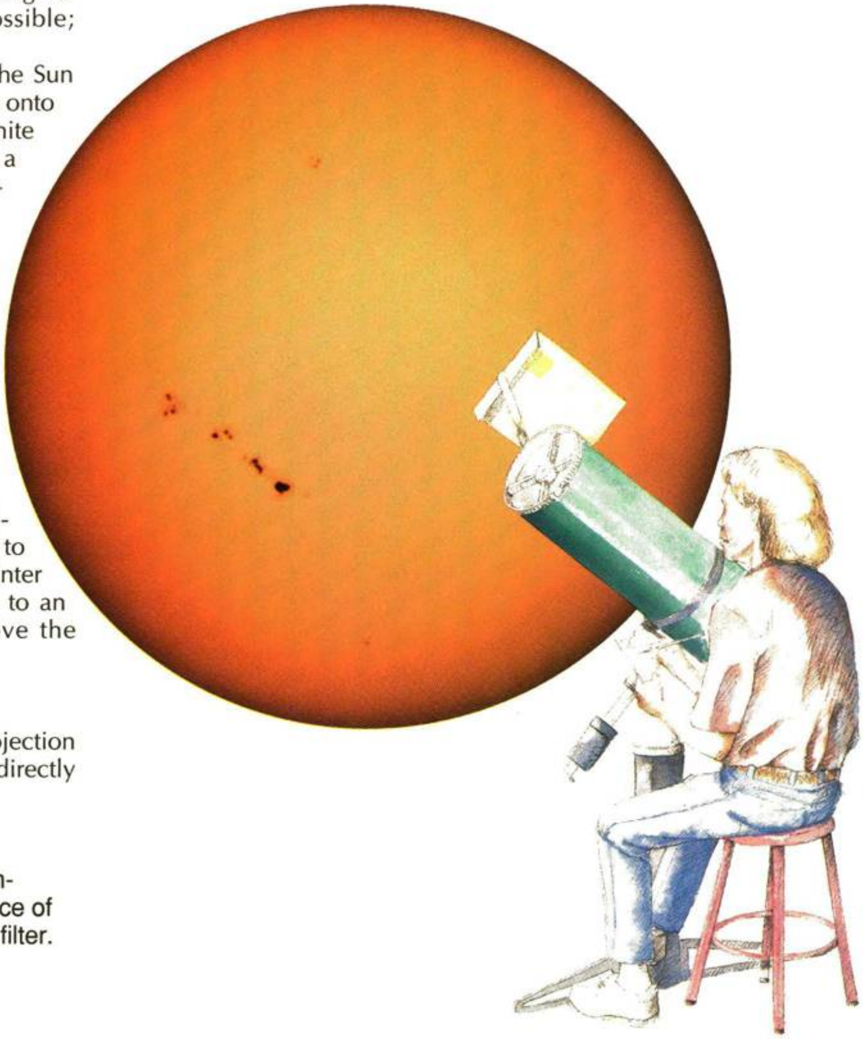
With the projection technique, more magnification generates a dimmer image. So you need to shield the screen from direct sunlight to spot fainter details. To get a closer look at a detail, switch to an eyepiece with a shorter focal length or move the screen farther from the eyepiece.

### A Filtered View

If juggling eyepieces, a telescope, and a projection screen doesn't seem like fun, observe the Sun directly through a solar filter mounted on the front of your telescope. Solar filters keep high intensity sunlight out of the telescope, which reduces the chance of damaging components and minimizes air turbulence inside the tube caused by heating. There are three types of commercial filters available: dyed glass, metal-coated plastic, and metal-coated glass.

Dyed glass filters are available through your local welding supply store. Ask for welder's glass shade No. 14, an extremely dark, green filter that few sources of light, save the Sun, can penetrate. Shade No. 14 is a rather specialized glass for a welding shop to stock — don't be surprised if they have to special-order it. These filters come in standard sizes of 2 x 4$^{1}/_{4}$ inches, perfectly sized to cover a pair of eyes (cover your eyes first and then look for the Sun!), and 4$^{1}/_{2}$ x 5$^{1}/_{4}$ inches, a reasonable size for the front end of a small telescope (be sure it covers the entire front aperture and is mounted securely so a flash of sunlight doesn't blind you). While dyed glass is well suited for casual observing, it is not optical-quality glass and may not produce sharp enough images for high-resolution photography or high-power observing.

The second type of filter has a layer of aluminum applied to a mylar base. Commercial mylar filters actually have two layers of metal-coated base so that any pinholes in one layer won't line up with those in the second layer. Some do-it-yourselfers purchase aluminized mylar separately and cut it to fit a needlepoint ring (available in many sizes from handicraft shops). Though images in these filters are a cold blue,



ASTRONOMY: Phil Kirchmeier

**A RISING ARC OF COOLING GAS**, a promnence, rises thousands of miles above the surface of the Sun in this photo taken through an $H\alpha$ solar filter.

they are very good because the base doesn't distort incoming light.

A third type of filter, the most expensive mentioned thus far, is metal-coated glass. These filters have nickel and chromium or other metals coated onto a piece of glass. Images in these filters are typically yellow or orange, colors some people find more pleasing than the blue or green images produced by mylar and dyed glass filters. Check with the manufacturer to be sure the coated surface of the filter is on the side facing the telescope rather than the side facing the sky. The former protects the delicate surface coating a little better.

### Photographing the Sun

Filtered telescopes work best for doing photography. By simply shooting prime focus through the telescope, it's very easy to capture a full-disk view of the Sun. Working with an f/10 or f/11 telescope, determine the exposure by taking the reciprocal of your film's speed (1/ASA). For example, exposures with 100 speed film and a typical f/10 Schmidt-Cassegrain would bracket around an optimal shutter speed of 1/125 second.

Schmidt-Cassegrain users need to remember one factor before firing the shutter. SCTs have a curved focal plane, which means an image focused in the center of the field of view is slightly out of focus at the edges. Faced with this reality, critical focus should center on the feature of interest. Less sharp features can be cropped out in the final print.

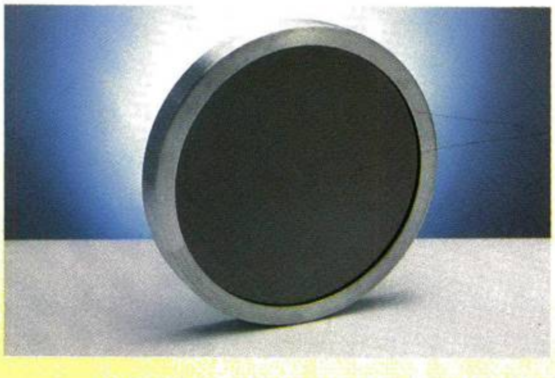
For more advanced photographers, some manufacturers make filters designed specifically for high resolution picture-taking. These filters transmit more light than a standard visual filter and allow for shorter exposures that "freeze" moments of steady atmospheric seeing. These filters are dangerous to look through since they transmit 10 times more light than standard filters. Focus and center a particular solar feature with a standard filter before switching to a high transmission filter.

Besides conventional still cameras, video and CCD cameras also work well for solar photography. Video cameras can record scenes in lapsed time, capturing events such as solar rotation, the slow evolution of sunspots, the explosion of a flare, and the rapid eruption of a prominence. The only challenge to shooting video is attaching the camera to the telescope and selecting the right eyepiece to project the image into the camera's lens. While CCD cameras are lighter and plug directly into the eyepiece holder, a potential pitfall is their sensi-

## Where To Buy Solar Filters

These companies make or sell a variety of solar filters. Asterisks show who market Hα filters.

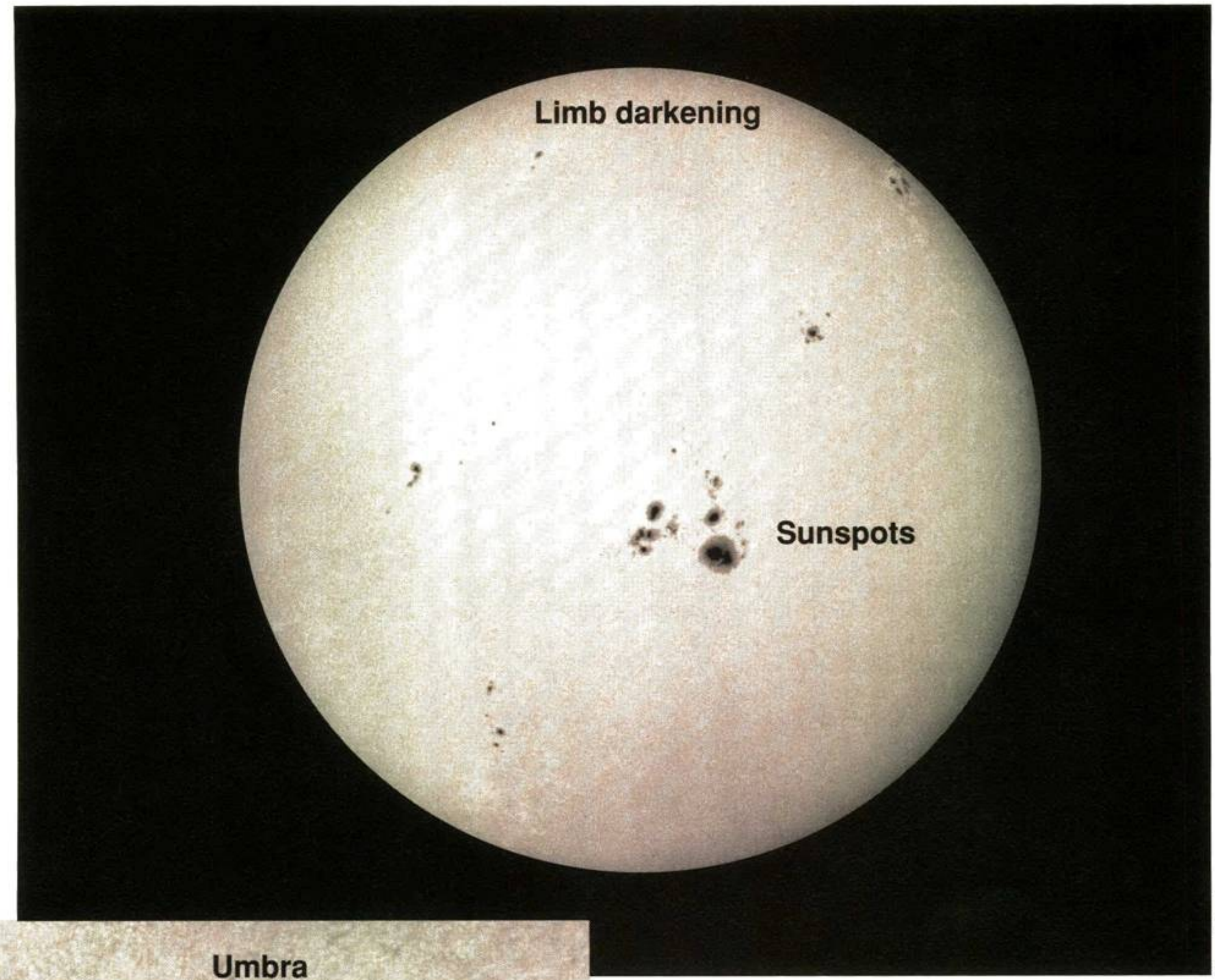
AbelExpress, 230 E. Main Street, Carnegie, PA 15106.
Astro-Physics, 11250 Forest Hills Road, Rockford, IL 61111, (815) 282-1513.*
Astronomical Innovations, P.O. Box 14853, Lenexa, KS 66285, (913) 894-5775.*
Celestron International, 2835 Columbia St., Torrance, CA 90503, (310) 328-9560.
DayStar Filter Corporation, P.O. Box 1290, Pomona, CA 91769, (714) 591-4673.*
Edwin Hirsch, 168 Lakeview Drive, RR 1, Tomkins Cove, NY 10986, (914) 786-3738.*
J.M.B. Inc., 20762 Richard, Trenton, MI 48183, (313) 675-3490.
Lumicon, 2111 Research Dr., #4, Livermore, CA 94550, (415) 447-9570.*
Orion Telescope Center, 2450 17th Avenue, P.O. Box 1158, Santa Cruz, CA 95061, (800) 447-1001.
Rainbow Symphony, 6860 Canby Avenue, Unit 120, Reseda, CA 91335, (818) 708-8400.
Roger W. Tuthill, Inc., Box 1086, 11 Tanglewood Lane, Mountainside, NJ 07092, (908) 232-1786.*
Spectra Astro Systems, 6631 Wilbur Ave., Suite 30, Reseda, CA 91335, (818) 343-1352.*
Tele Vue Optics, Inc., 100 Route 59, Suffern, NY 10901, (914) 357-9522.*
Thousand Oaks Optical, Box 5044-289, Dept. A, Thousand Oaks, CA 91359, (805) 491-3642.*



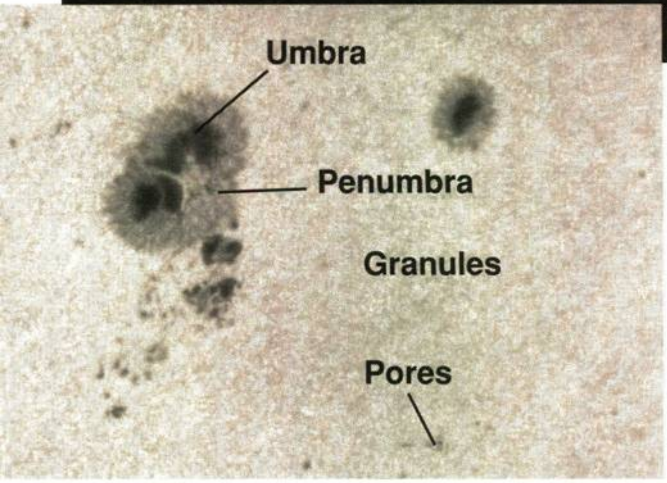
**Metal-coated glass solar filter**

ASTRONOMY: Darla Evans

**Metal-coated mylar solar filter**



Gerard Therin



Gordon Garcia

**OBVIOUS DETAIL SUCH AS** sunspots and limb darkening appear at low power. Closer scrutiny reveals pores, granules, and sunspot features such as umbrae and penumbrae. Pores fade or linger to form sunspots. Granules are cells of hot, rising gas; sunspots are cooler areas.

tivity. You may need more filtering to prevent overexposure with even their shortest shutter times. For both video and CCDs, a rock-steady mount is necessary to maintain pointing accuracy.

### Toward a Steady Sun

The steadier the atmosphere, the more you'll see and photograph; the right observing site reduces the chances for poor seeing. An ideal site overlooks a large area that has constant temperature, a lake or grassy field for example. Sites near parking lots and rooftops are likely to have poor image stability because of the heat they generate. Time of day is also an important factor; views are sharper in the early morning because the Earth has cooled off all night and reached the same temperature as the surrounding air.

Contrast is just as important as sharpness. An image with good contrast is vastly improved if the telescope's optics are cleaned before solar observing. Dust and dirt on the optics conspire to reduce the contrast of the image. Clean optics are especially important when looking for subtle features like solar prominences. Contrast also suffers when there are thin clouds in front of the Sun, so keep an eye on the sky. And don't forget to check the solar filter; pinholes in the coating of a solar filter let in flashes of bright sunlight, which reduce contrast. Cover these holes with black paint.

Stray light can also be a problem. To block it, slip a rubber eyecup on the eyepiece or drape a black hood over your head. Try building a small sunshade to keep direct sunlight from falling on your face while looking through the eyepiece. An even bigger sunshade would keep both you and the telescope in shadow. As with all

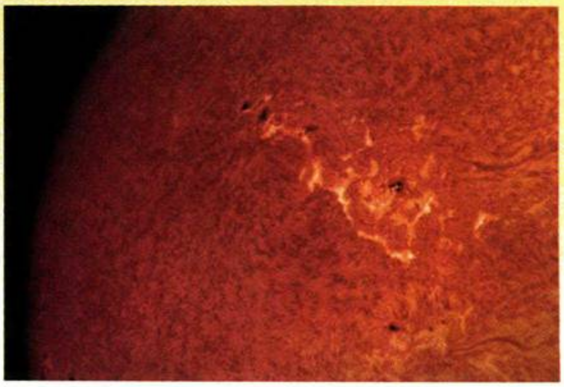
# The Sun in a Different Light

Light we see through a conventional solar filter comes from the Sun's photosphere, a layer that emits the white light we call sunlight. But above the photosphere is yet another layer, the chromosphere. In the chromosphere lie active features like solar flares, prominences, and filaments, and plage regions around sunspots. To get a sharper look at those details, we need to use a filter that allows only light from the chromosphere to reach the eyepiece. Enter the Hα filter, which passes light at 6562.8 angstroms (Å), a wavelength of light produced in the chromosphere.

All Hα filters center on the 6562.8 Å region of the solar spectrum, with more expensive filters tuning in closer to that spectral line. A broadband filter with a 1 Å bandwidth (that's how Hα filters are specified) shows only large features in the chromosphere, such as giant prominences and bright solar flares. Those filters usually cost less than $700. Narrowband filters, which pass light from only 0.5 Å either side of 6562.8 Å, show the most detail but are more expensive, costing at least $2,000.

Hα filters are enclosed in a temperature-controlled chamber. How warm the filter is determines how accurately it transmits the proper bandwidth for Hα solar observing.

Hα filters need to work in tandem with a red energy rejection filter (purchased separately for about $150). Mounted on the front of the telescope, this filter absorbs much of the Sun's light to protect the Hα filter from heat damage.

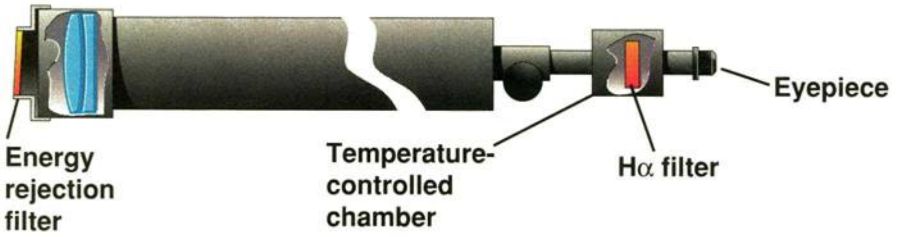


Don Trombino

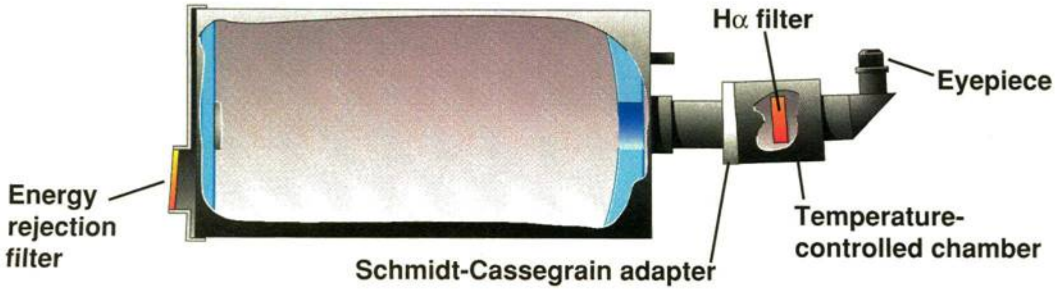
**A GIANT SOLAR FLARE** looks like a bright ribbon of light against the Sun's churning face in this Hα photo taken on June 10, 1991.

For a filter to work at all, you must be able to stop down your telescope to at least f/30. When incoming light converges sharply to focus, as it does in a fast f/ratio telescope, it broadens an Hα filter's bandwidth, which makes features appear more ill-defined. For this reason, long-focus refractors and Schmidt-Cassegrain telescopes work best for Hα observing and photography. When SCTs are combined with a pre-filter that stops down their aperture, light enters the filter assembly as a parallel beam, essential if the filter is to work properly.

Hydrogen-alpha filter on a refractor



Hydrogen-alpha filter on a Schmidt-Cassegrain



ASTRONOMY: Phil Kirchmeier

observing, comfort helps and being in the shade keeps you cool. Except during winter, you can get quite hot while observing the Sun. With this in mind, wear light-colored, lightweight clothing.

### Here Comes the Sun

When all the elements line up — clean optics, a good filter, an excellent site, clear skies, and comfort — you'll be astounded at what the Sun's photosphere (its visible surface) looks like. Your first view may be surprising: the Sun's edge, called the limb, roils and boils. This is the churning of Earth's atmosphere, not a display of solar activity. Ignore the wavy disk edge and look instead just inside the limb. Compare this area with the center of the Sun's disk. Notice the limb is darker, an effect called limb darkening. This occurs because light from the center of the disk doesn't travel through as much of the Sun's atmosphere to reach us as light that comes from the limb.

In addition to limb darkening, you may notice some medium or large sunspots. These are cooler areas on the Sun (2,000 kelvins cooler than the rest of the photosphere). They range in size from a few thousand to tens of thousands of kilometers across. Sunspots contain intense magnetic fields that reach several thousand gauss (Earth's field is about 0.5 gauss) and change in size and shape daily as turbulent gases swirl around and within them.

Try to guess which sunspots will last the two weeks it takes them to cross the Sun's face. Use sunspots to measure the Sun's rotation and figure out how it varies with solar latitude. While individual sunspots sometimes appear, they usually form in groups. The darkest part of a spot is the umbra; several sunspots together may be surrounded by a lighter penumbra. Other features surrounding sunspots are faculae, tiny patches that appear brighter than other portions of the photosphere. Faculae are always present but are seen best around sunspots near the limb.

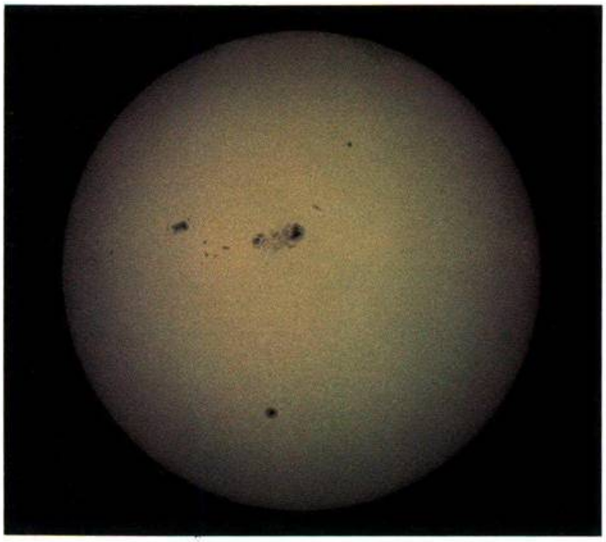
The region where sunspots form moves as well. Over the course of an 11-year sunspot cycle, they not only vary in number, size, and complexity, but form at different latitudes on the Sun. At sunspot minimum (the Sun's coming out of one now), they form close to 30° latitude. Over the course of a few years, they originate closer to the equator.

In steady seeing you'll see pores scattered on the photosphere, small darkenings only a few seconds of arc or less across (1" is about 1,000 km at the Sun's distance). Pores usually disappear in a few hours' time but sometimes grow into large sunspots.

Granules are another delicate feature with limited lifetimes. Under good seeing, they appear as a low contrast rice-grain pattern across the disk. Granules are the sites of hot, rising material in the Sun's topmost layer. (Similar convective cells appear in a pot of very hot oatmeal.)

But when it comes to looking for detail, a hydrogen-alpha filter opens up a whole new star for study (see "The Sun in a Different Light," opposite). In Hα light, sunspot numbrae may look simpler, but its penumbra is replaced by threadlike spokes that radiate out from the umbra.

Other features seen in white light look different in Hα light. Faculae, the small, bright patches seen around sunspots in white light in Hα, are referred to as plage. Plages are active regions that linger long after the sunspots they are associated with disappear. In these active regions, strong magnetic fields sometimes twist and distort to the breaking point, generating an explosive brightening called a solar flare. Solar flares in Hα linger between a few minutes and a few hours.



Rick Dilsizian

**THE SUN LOOKS YELLOW** through metal-coated glass filters, a popular solar filter. Another popular solar filter, mylar, makes the Sun appear blue.

Looking at the Sun's limb under high magnification in Hα shows what are called spicules, hairlike threads that stick up for minutes at a time. Arcing high above the spicules are clouds of gas supported by magnetic fields in the chromosphere called prominences (calling them flares is incorrect). Prominences have a variety of forms and shapes, such as simple clouds, flames, hedgerows, and loops. When seen against the disk, prominences appear as dark streaks called filaments.

Filaments and prominences come in active or quiescent forms. Quiescent prominences last for months at a time with few changes and then in the course of a few minutes suddenly rise upward and dissipate. Flares are associated with these changes. Some prominences simply take off into space, dissipating as they join the solar wind. Sometimes the foot of the prominence remains attached to the chromosphere while the other end blows away. A prominence that starts moving upward only to fall back to the Sun is called a surge.

In Hα or white light, the Sun offers plenty of opportunity for both observing and photography. Since its face changes from day to day, no two observing sessions are ever the same. Best of all, with solar observing there are no late night hours to compete against the requirements of family and job. Whether you make a quick, eye-protected glance to check sunspot numbers or spend hours making detailed studies of faculae or prominences, the reward of solar observing is a better understanding of our star. This makes for a better appreciation of other stars found in the realm of night as well. □

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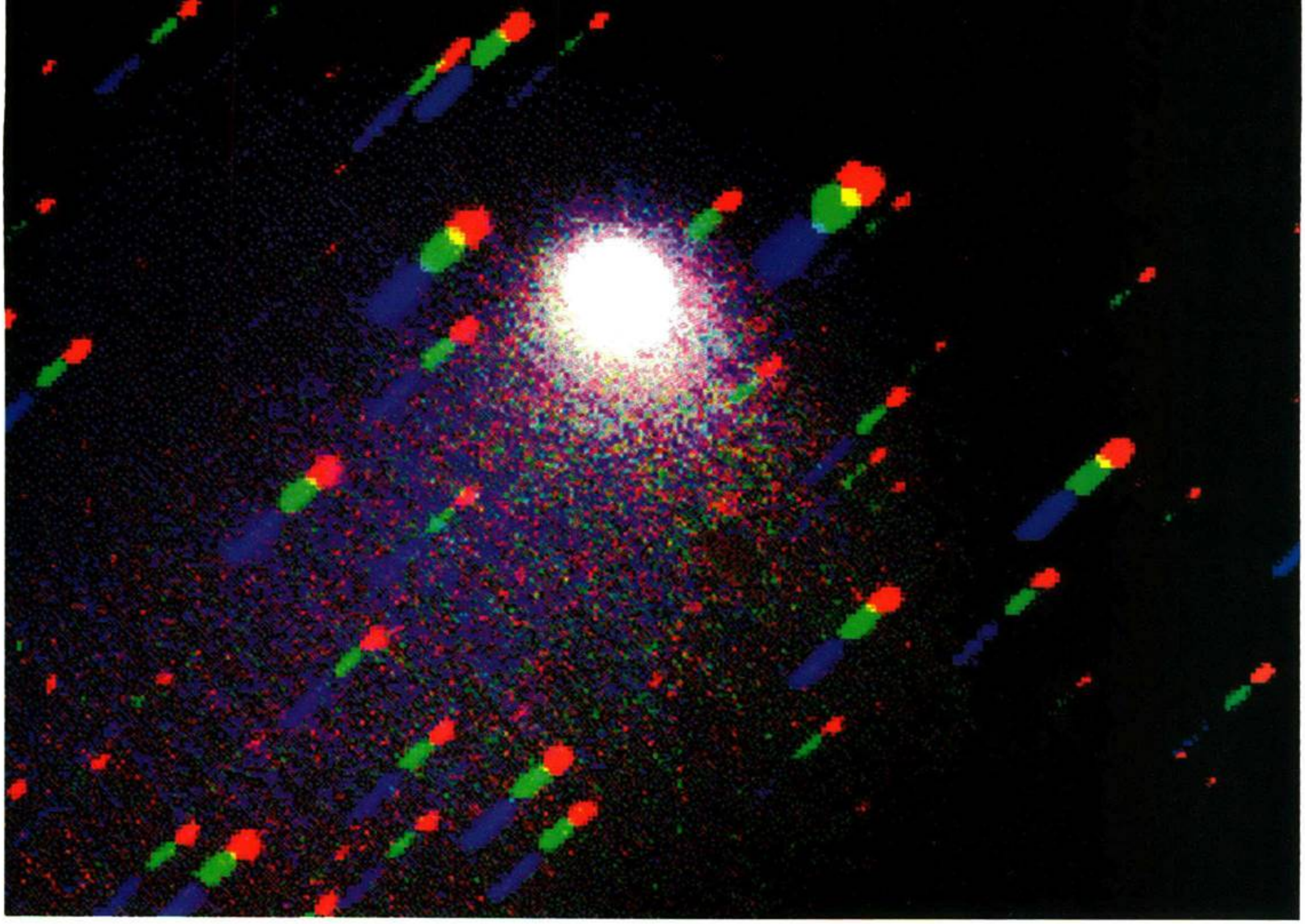
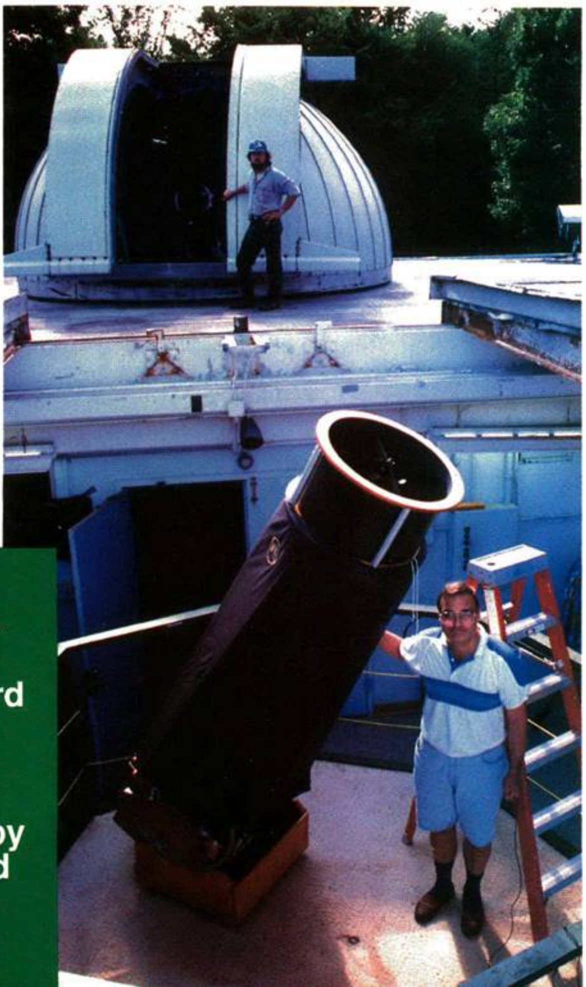
*Stephen J. Edberg observes the Sun from his home near Pasadena, California, when he's not working on NASA's Galileo and Cassini projects.*



# Catching Comets With a CCD



A pioneering technique allows astroimagers to electronically record detailed images of comets in color.

Story and images by Glenn Gombert and John Chumack

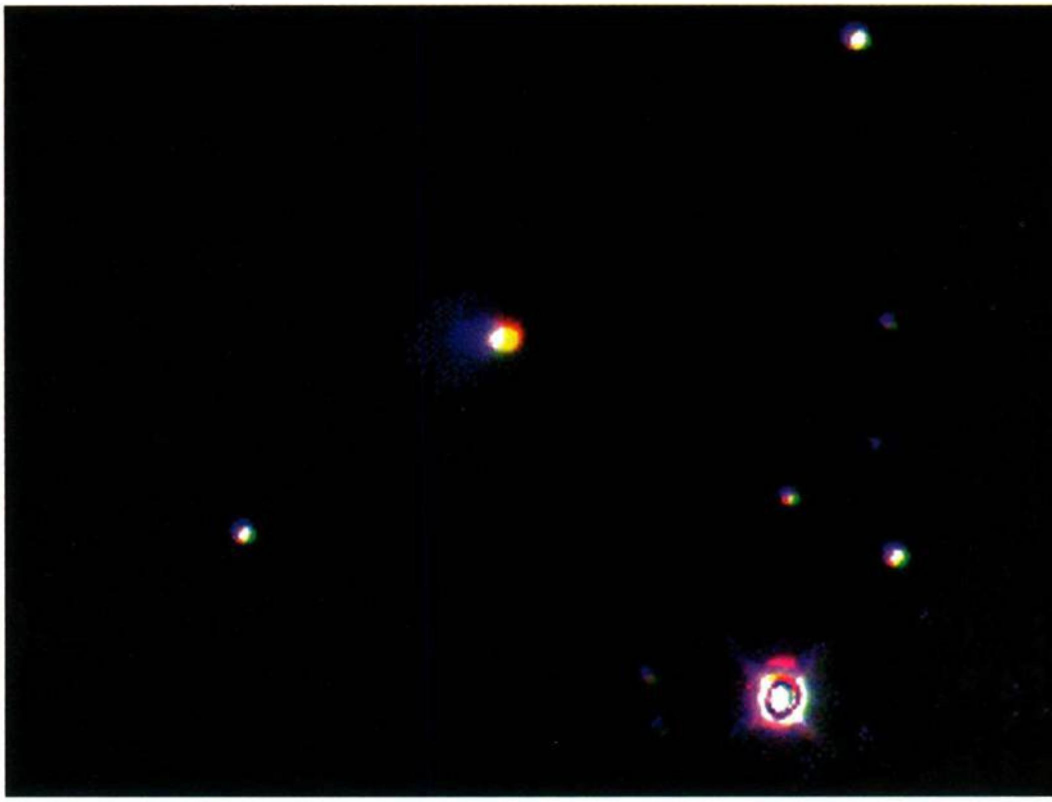
Electronic images of the sky are appearing in the pages of ASTRONOMY in ever increasing numbers. Such imaging, which uses a CCD chip and digital storage rather than conventional photographic film, permits storing and manipulating data in the images with ease and shortens the exposure times needed for capturing faint objects. The technique works well for normal, "stationary" sky objects: galaxies, clusters, and nebulae. Electronic imaging, however, hasn't worked well with comets.

The problem is that comets move at a different rate and in different directions across the sky than the stars used for guiding an exposure. Comets are usually faint, so they require fairly long exposures even with electronic imaging. To shoot comets in color, you need to take three exposures — red, green, and blue — in fairly rapid succession so the comet lies in essentially the same starfield and you get a satisfying result when combining the frames into a single image. These factors conspire to make imaging comets with a CCD camera tricky — or asteroids, for that matter, which also move relative to the star background. Over the past several months, however, we have developed a process that minimizes the trouble of recording comets with a CCD camera while maximizing the results.

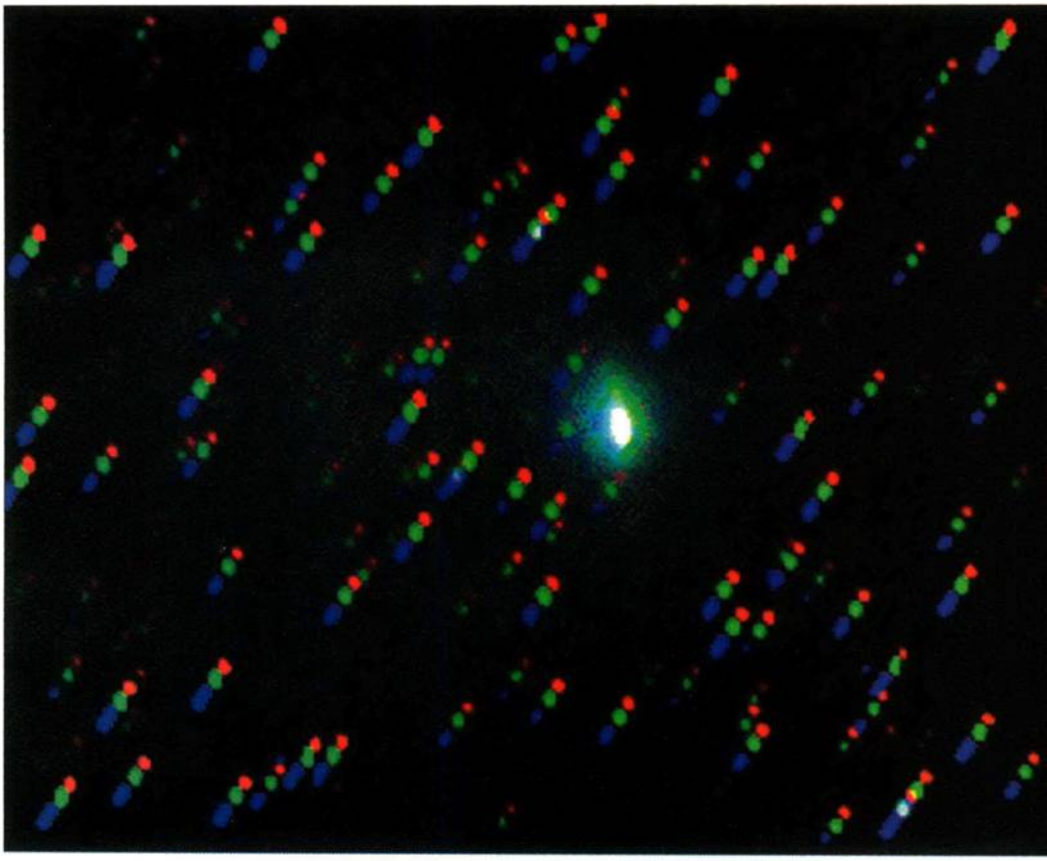
The chief dilemma with comets results from their motion. If you do the conventional thing and guide on a star near the comet, you'll get pinpoint stars but details in the comet will smear out over the length of an exposure. We first encountered this when we used John's 16-inch f/4.5 reflector and an SBIG ST-6 CCD camera to record Comet Mueller (1993a). We got a sharp starfield and a blurred image of Comet Mueller.

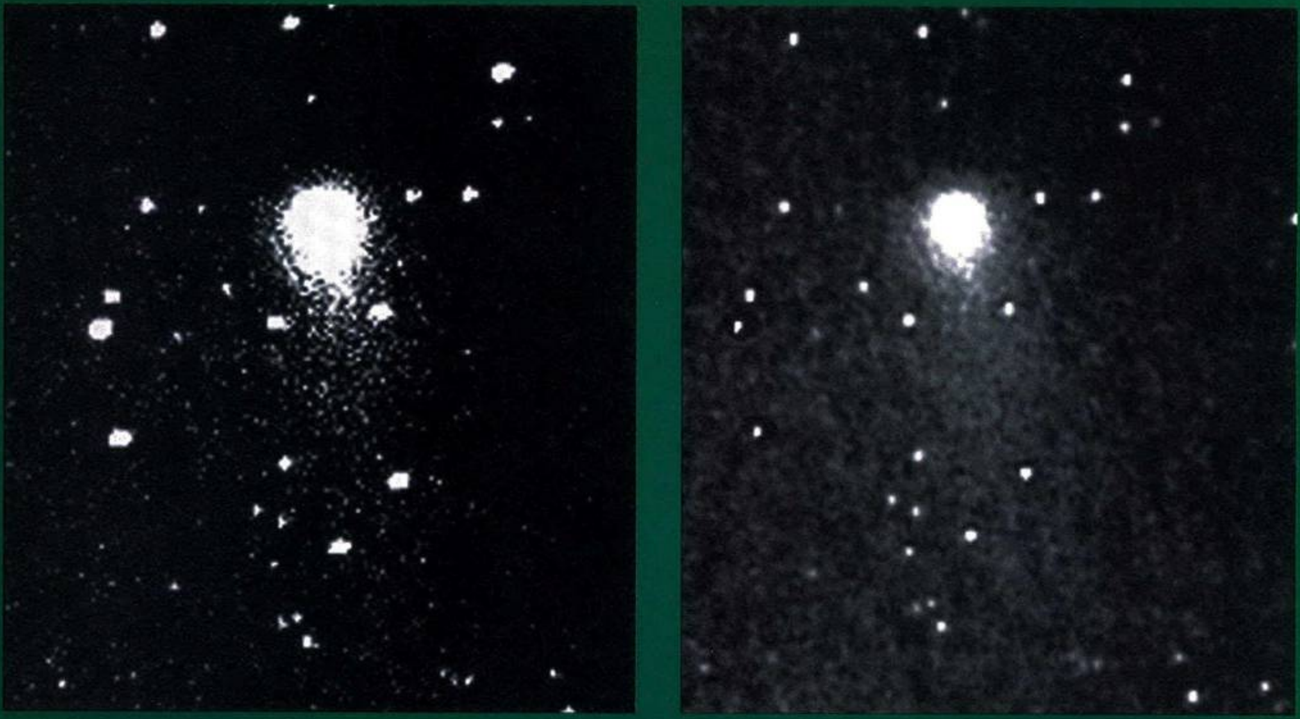
The best way to get around this in comet photography is called step-guiding. The method seeks to estimate the angle and speed of motion of the comet with respect to the background starfield and then guide the telescope to compensate for this apparent motion. Step-guiding produces a sharp, detailed image of the comet with trailed stars, and can also be used in recording comets with a CCD camera.

Another possibility exists, however. Using the so-called track-and-accumulate mode of the ST-6 camera, we first take a short exposure (typically 30 seconds) of the comet's field. From this exposure, we choose a guidestar on the computer display.

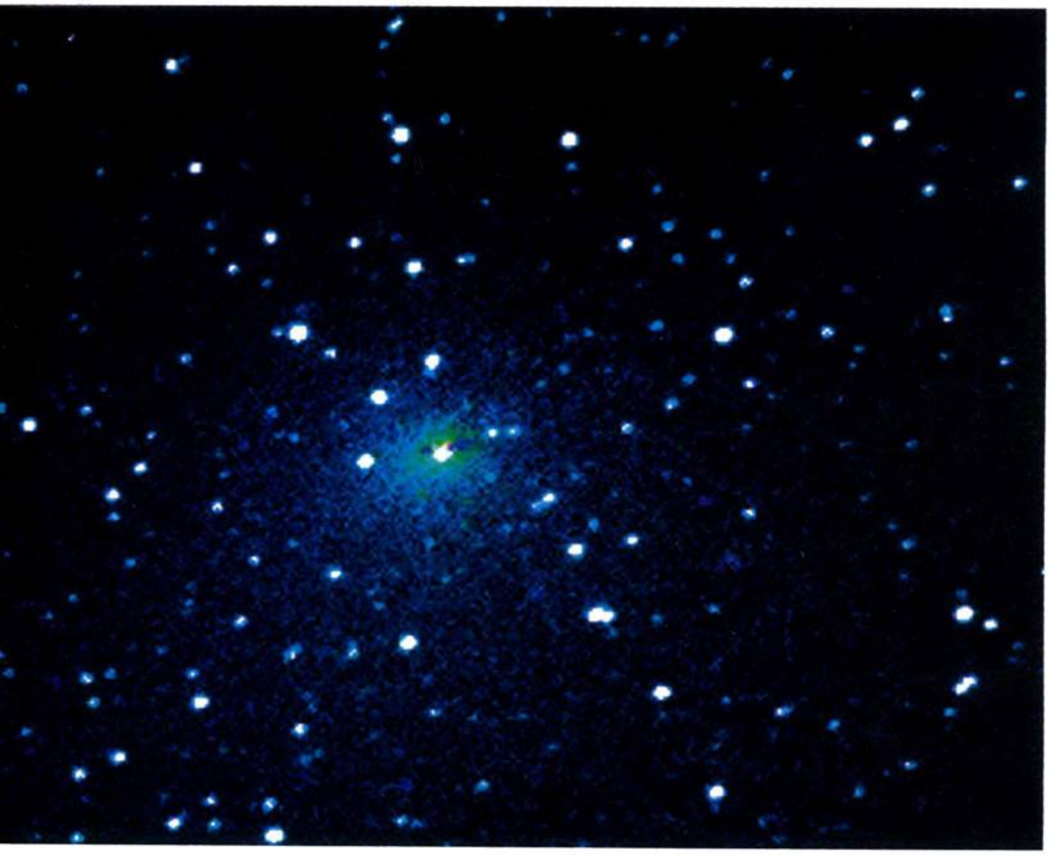


**COMETS BRIGHT AND FAINT** record nicely on a CCD, as with Mueller (1993a), opposite page top, P/Tempel 1 (1993c), above, and P/Borrelly (1994l), below. Authors Gombert and Chumack (opposite page, bottom) use a 16-inch reflector and an ST-6 CCD camera to record comets.





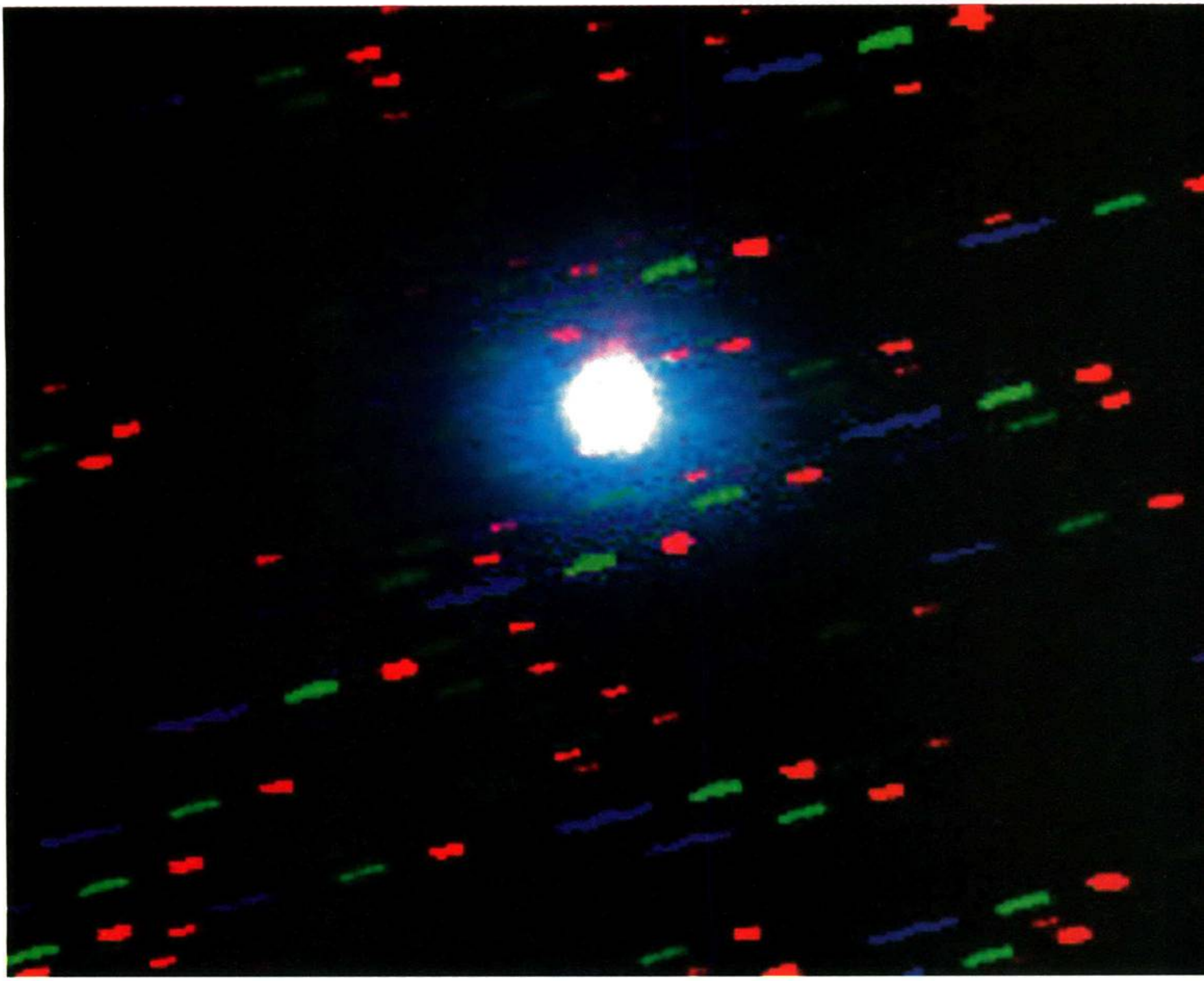
**BEFORE AND AFTER**: *Hidden Image*, a program for image processing, effectively removes atmospheric blurring from a raw image of Comet P/Schwassman-Wachmann 2 (left) and transforms it into a sharper picture (right).



**COMET NAKAMURA-NISHIMURA-MACHHOLZ** (1994m), left, has a sharp, starlike nucleus and bluish coma in this CCD image.

We then take a long series of very short exposures one right after the other. We combine the images using the guide star as a registration point from one image to the next. This helps to compensate for inaccuracies in polar alignment and periodic error in the telescope's drive system. The final result is an image nearly equivalent to a single long exposure.

Then the process takes another evolutionary step. By combining frames and using the track-and-accumulate mode but tracking and registering on the core of the comet, we found we could produce striking tricolor images of Comet Mueller (see page 72). This not only provides a deep, detailed image of the comet with relative ease, but preserves the maximum amount of detail in the comet itself and shows the object in striking color. We feel the technique will be of great interest to astroimagers interested in high-resolution cometary imaging. We have used this



technique to image a number of comets, including comets Kushida (1994a), P/Schwassman-Wachmann 2, P/Shoemaker-Levy 9 (1993e), P/Tempel 1 (1993c), McNaught-Russell (1993v), Nakamura-Nishimura-Machholz (1994m), and P/Machholz 2 (1994o).

Obtaining the CCD image is only step one, however. The real fun comes with image processing, using the computer as darkroom. We have been using Sehgal Corp.'s *Hidden Image* program to try to bring out as much detail as possible in the comae and tails of the comets. The program employs a background star in the field to estimate the blurring and atmospheric effects in the image and to remove the smearing and sharpen the image. The technique is essentially the same as that used to help the fuzzy images delivered by the Hubble Space Telescope before its fix.

However, with our comet images we track on the comet and therefore trail the stars. That's where the preliminary 30-second exposure of the starfield comes in. We take this to get an untrailed image of a star in the field of the comet to use with *Hidden Image*. We extract a relatively bright star from this original image and save it in the computer so *Hidden Image* can use its "point-spread function" to derive parameters for sharpening the image, what astro-imagers call deconvolving it.

The technique works quite well with comets. The combination of the track-and-accumulate mode of the ST-6 and the *Hidden Image* program opens a new world for comet imaging. A similar method could be used with CCD cameras without a track-and-accumulate mode. This could be done by taking a number of short exposures (30 to 60 seconds) and combining them, with the comet's nucleus serving as the registration point. Either way, sharper, clearer pictures of comets will show up in the pages of ASTRONOMY's future issues. ☐

**FROZEN IN SPACE**, Comet McNaught-Russell (1993v) is a fat ball of glowing light in a field of multicolored star trails.

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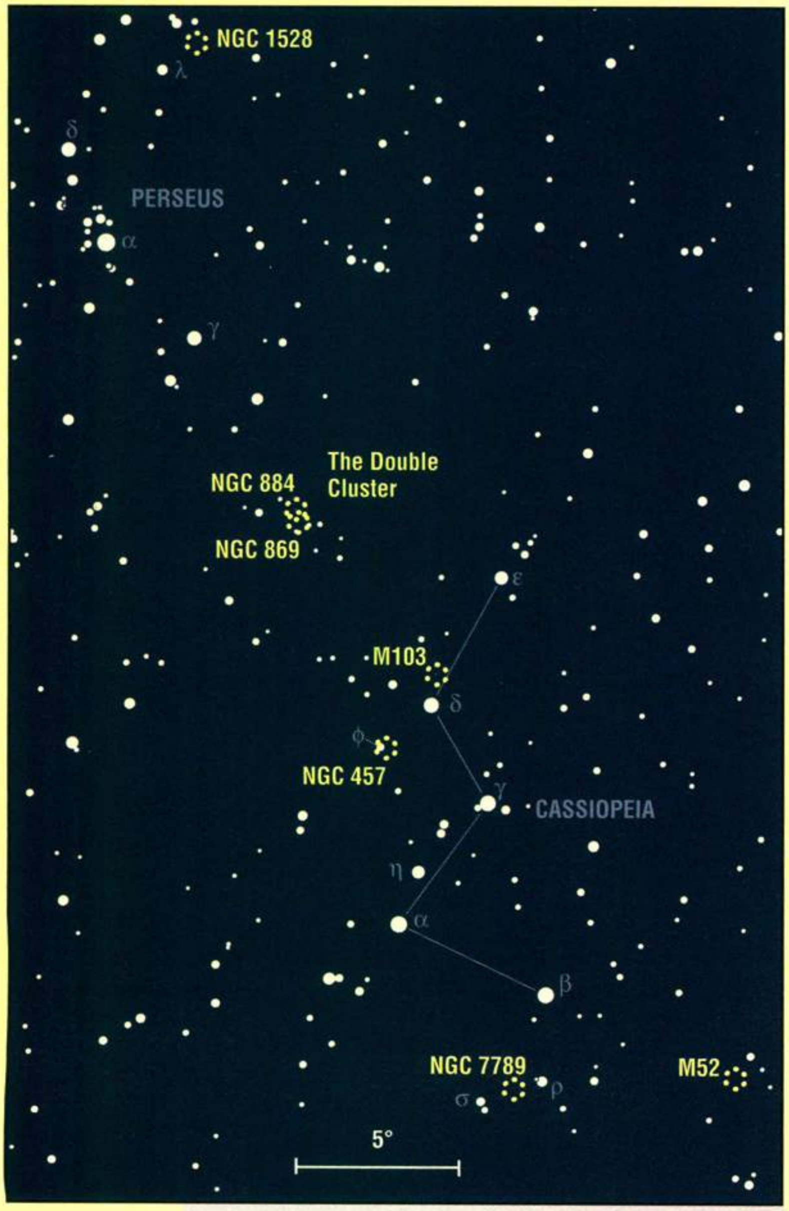
*Glenn Gombert and John Chumack enthusiastically image the sky using a variety of telescopes at John Bryan State Park outside Dayton, Ohio.*

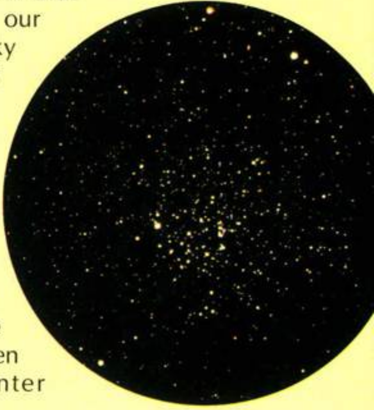
# Seven Easy Star Clusters



It's wintertime and a special place along the winter Milky Way demands our attention. Enter the realm of the open clusters.

by John Shibley

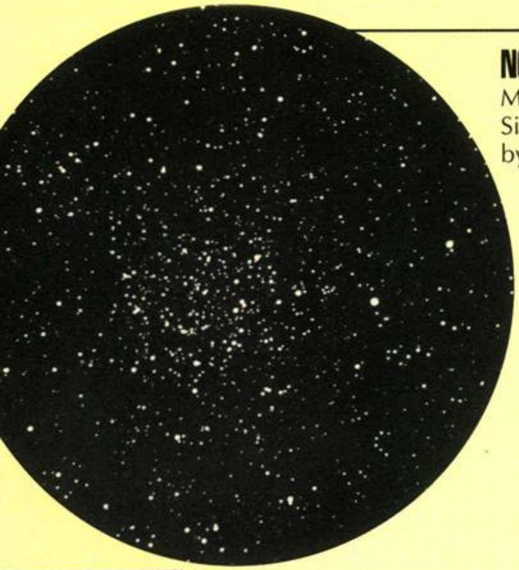
As night falls on February evenings, the unmistakable W of Cassiopeia suspends itself high in the northwest, perched on one side and opened to the north. Aside from making its home constellation easy to spot, the W also flags a section of the sky rich in open star clusters. Most of the clusters in this area populate a spiral arm that lies one out from the arm our Sun occupies in the Milky Way. Tonight let's meet some of those clusters, five of which are some of the easiest clusters to find in the winter sky. All you'll need are binoculars or a small telescope working at low power (30x). If you've got a larger telescope, all the more fun . . . you'll see even deeper and pick up fainter cluster members.



To find our first cluster tonight, draw a line from Alpha (α) Cassiopeiae through Beta (β) Cas and extend it the same distance that separates both stars. You should see in binoculars or a finder scope a nebulous mass about one third the size of a Full Moon. This is **M52** (NGC 7654), discovered by Charles Messier (he compiled the Messier catalog) in September 1774. Binoculars resolve several stars against the nebulosity, which appears to extend to the northeast. An 8-inch reveals more members, along with a moderately bright orange star that seems to be a part of the cluster. All told, there are 100 stars in this cluster that shine with an integrated magnitude of 6.9. M52 lies about 5,400 light-years from us and is about 15 light-years in diameter.

Moving south and east from M52, we next come to **NGC 7789**. It's nestled between Rho (ρ) and Sigma (σ) Cas just off the western edge of the W. In binoculars NGC 7789 looks like a hazy patch of light floating in the winter Milky Way. Shining at magnitude of 6.7, it has a diameter of 16'. A 3-inch starts resolving stars, with the field becoming peppered with stars in a 6-inch. In larger aperture scopes (10-inch or above), the cluster appears to be criss-crossed by dark lanes. This is an optical illusion; your brain connects myriads of stars into chains, and the gaps between them appear to form lanes. NGC 7789 has about 300 members packed into an area half the size of a Full Moon. It lies about 6,000 light-years away and is 50 light-years in diameter.

Our next cluster forms an animal; the kind is up to you. **NGC 457** sits 2° southwest of Gamma (γ) Cas. One bright foreground star, Phi (π), is smack in the middle of it. Phi and another 5th-magnitude star show up in binoculars against the cluster's fuzzy patch of light, which spreads west and slightly north. A 3-inch scope resolves about two dozen stars, while an 8-inch reveals several dozen. If you look carefully, you'll see



**NGC 7789**
Mag. 6.7
Size 16'
by J. C. Mirtle

**M52**
Mag. 6.9
Size 13'
by Jack Newton

**NGC 457**
Mag. 6.4
Size 13'
by Lee Coombs

**M103**
Mag. 7.4
Size 6'
by Lee Coombs

**Double Cluster, NGC 869 and NGC 884**

Mag. 4.3
(NGC 869); 4.4
(NGC 884)
Size (each) 30'
by Mark Killion

**NGC 1528**
Mag. 6.4
Size 24'
by Lee Coombs

that two bright stars form the eyes of a lobster or an owl, with scattered rows of faint stars making up the claws or wings, and the rest of the cluster forming a body. Our lobster/owl has its claws/wings outstretched, seemingly waving back through the eyepiece. NGC 457 shines at magnitude 6.4 and covers 13'. It lies some 9,000 light-years from Earth and is about 30 light-years across.

Nestled 1° northeast of Delta (δ) Cas we find our next target: **M103** (NGC 581). Composed of about 25 unresolved stars in a 6' area, this Messier object looks like a fan-shaped streak in binoculars or a finder. An 8-inch reveals six 10th-magnitude stars in a field of 11th- to 12th-magnitude stars. M103 is 8,500 light-years distant and about 15 light-years in diameter.

Moving left we find two of the finest star clusters in the sky. Look for the **Double Cluster**, NGC 869 and NGC 884, as a naked-eye, bifurcated fuzz between Cassiopeia's W and the pointed top of Perseus. Each cluster is so bright (almost magnitude 4.5) that early celestial cartographers gave the two clusters the star designations h and Chi (χ) Persei. Their true nature is betrayed with even the slightest optical aid. Binoculars show each to have over a hundred stars, with the westernmost, NGC 869, appearing more compact. Small scopes reveal more stars by the hundreds, with the field dominated by bright blue and white stars. Each cluster covers an area the size of a Full Moon, and curiously has a red star in its center. NGC 869 has 200 stars and is 7,200 light-years away; NGC 884 has 150 stars and lies 7,500 light-years distant. Each cluster is about 70 light-years across.

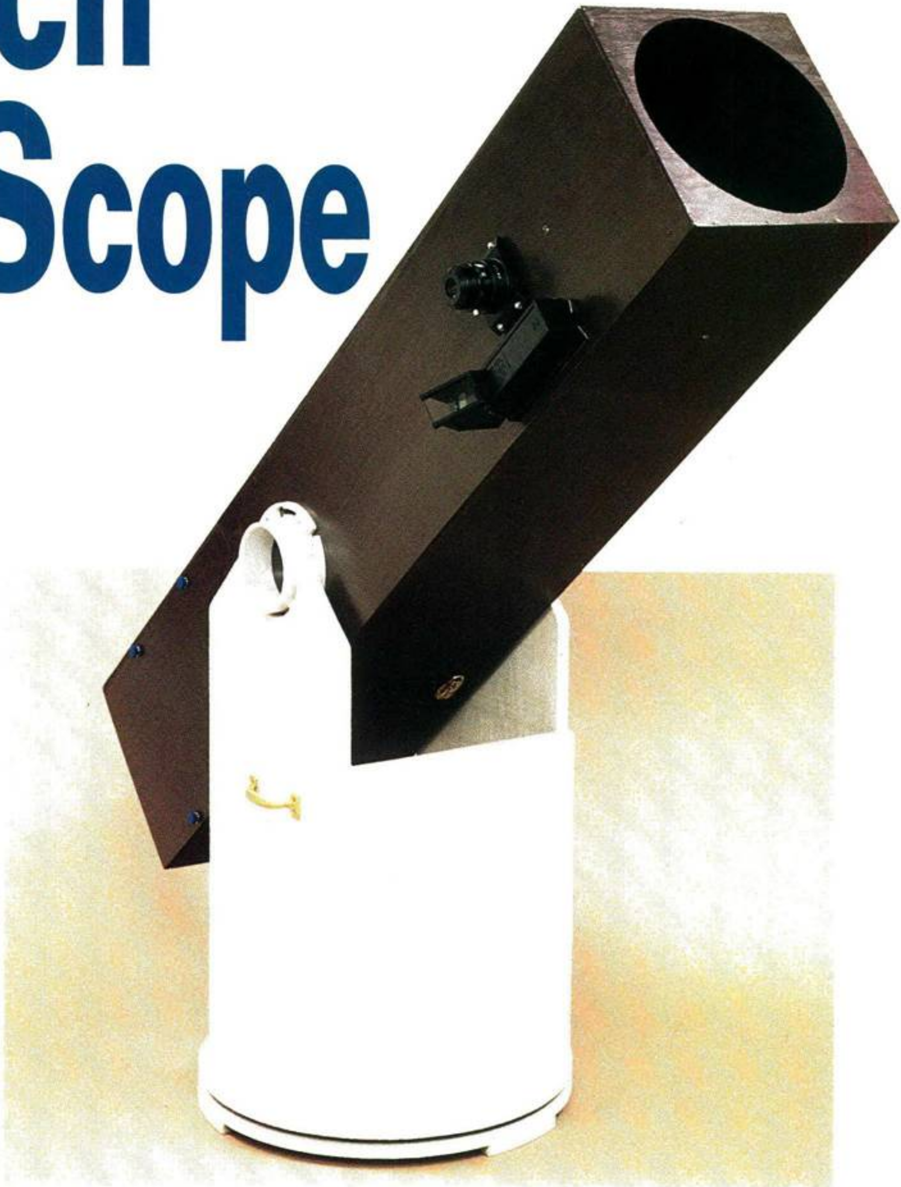
Our final cluster of the night resides squarely in Perseus, about 1.5° northeast of Lambda (λ) Persei: **NGC 1528**. Outshone by its brighter cousins in Cassiopeia, this object is nonetheless easy to find and worth the look. Binoculars show it to be a fuzzy magnitude 6.4 glow some 24' across, with one or two bright members resolved. An 8-inch shows 40-plus stars arranged in pairs and triplets, a 10-inch, up to 50 stars. NGC 1528 is the closest cluster to Earth we'll see tonight at 2,600 light-years away.

So concludes our frosty jaunt through Cassiopeia and Perseus. If you've enjoyed the tour, don't forget there are many more fascinating sights arrayed along the winter Milky Way. There lie still more stellar wonders in the constellations Auriga, Gemini, and Monoceros. But that's another story! □

# Completing the 10-inch PortaScope

Making the mirror cell, installing the optics, and collimating the scope gets this home-built scope ready for its first observing session.

by David Bruning



All photos by Chris Becker, ASTRONOMY

The fun is about to begin. After building the tube and altazimuth mount as outlined in part one of this series (January 1995), it's time to work on the optics. With just a few more hours work, the scope will be ready to focus the light of faint nebulae and distant galaxies.

The final bit of work falls into three parts. The first part, the primary mirror cell, will take the longest, requiring several hours to assemble. It's the only major construction step remaining, but one of the most important of the project. The second part consists of installing the mirrors, focuser, and finderscope. This is the most precise step of the project. And signaling the debut of the wood, screws, and glass as a working telescope, the final part involves aligning the optics.

### A Better Mirror Cell

A primary mirror cell has several functions. It holds the mirror firmly but without pinching to avoid introducing aberrations, or flaws, into the image. It prevents the mirror from falling out of the tube when pointing down. It allows easy alignment of the mirror. To avoid poor images, it should also help the mirror equalize as fast as possible with the air temperature when taken outdoors.

The PortaScope uses a wooden mirror cell for ease of construction and good thermal properties. The cell has a three-point support for the mirror. A 10-inch mirror is near the useful limits of a three-point support, especially for the thin mirrors used in Dobsonian scopes. Proper placement of the three supports will maintain this cell's effectiveness. Telescope makers who demand perfect optical performance may wish to investigate building or buying a nine-point cell, which supports the mirror's weight more evenly than a three-point cell does. (See the books listed in Resources in the back of this issue.)

Although some telescope makers advocate supporting the mirror at its edge, a large mirror in such a cell will sag at the center, causing the image to become distorted. The supports should sit 120° apart and about two-thirds of a radius away from the center. This choice places about half of the mirror area inside the supports and half outside.

Three posts support the mirror when the scope is tilted. Nylon washers that barely touch the mirror's surface prevent the mirror from tipping out of the cell.

The PortaScope uses a novel, rectangular alignment system. Most mirror cells use a set of three screws arranged in an equilateral triangle for adjusting the mirror position. Anyone who has aligned a mirror in such a support knows the frustration of having to adjust at least two screws to make the mirror move in a given direction. A rectangular system makes it easy to move the mirror corresponding to the up-and-down and left-and-right directions seen through the focuser.

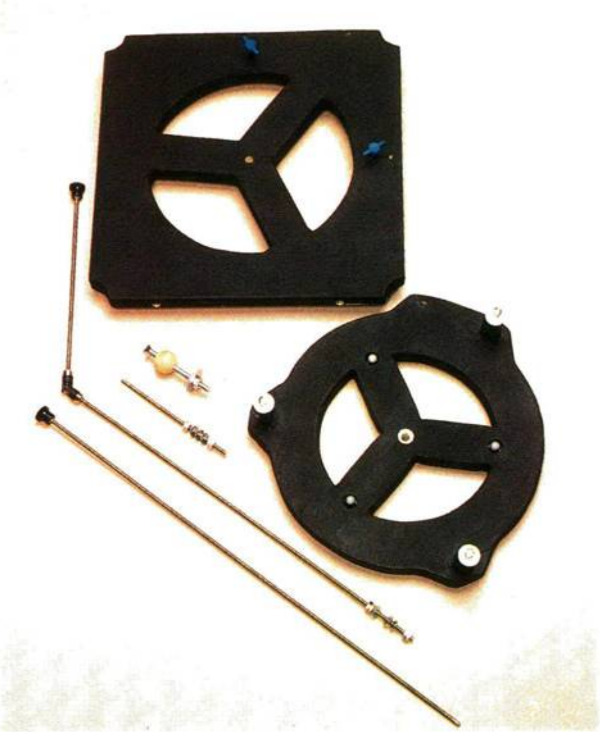
The adjustments use push-pull screws instead of springs. Springs can change tension and allow a single adjustment screw to turn and, thus, affect the mirror alignment. Pairs of screws apply opposing forces to maintain the alignment.

Another tiresome aspect of mirror collimation is its back-and-forth procedure — look through the focuser to see which way to move the mirror, step to the back of the scope and twist a screw, go back to the focuser to see if it was the right way, adjust the screw again, look again, twist another screw, step back and look again, and so on. The PortaScope removes this frustration by using threaded rods that permit you to collimate the scope conveniently from the focuser. Just look through the focuser and turn the two rods until the mirror is situated perfectly. Then tighten the push screws to lock the mirror in place. You shouldn't have to adjust this cell's alignment often but when you do, it'll be a snap.

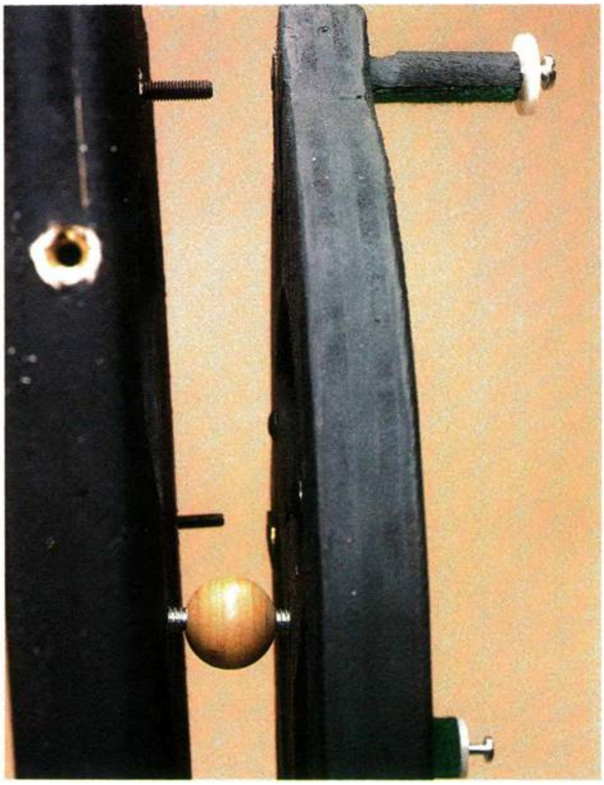
### Making the Cell

Although this mirror cell has lots of features, making it is easy. From the 3/4" plywood leftover from making the altazimuth mount, cut a 12" square and an 11" square. The larger piece forms the base that attaches to the tube, and the smaller piece forms the support for the mirror. Notch the corners of the 12" square piece so it can slide over the glue blocks in the mirror box.

A solid base blocks air movement through the tube, producing poor images. Yet the base also needs to act as a light baffle, preventing light reflected by the ground from entering the tube. A solution is to cut three holes near the center of the base. Mark the center of the base and then draw a circle about 4" in radius. Draw three legs 120° apart and about 1 1/2" wide, extending from the center to the edge of the circle. Using a saber saw, cut out the segments between the legs. Drill a 5/16" hole



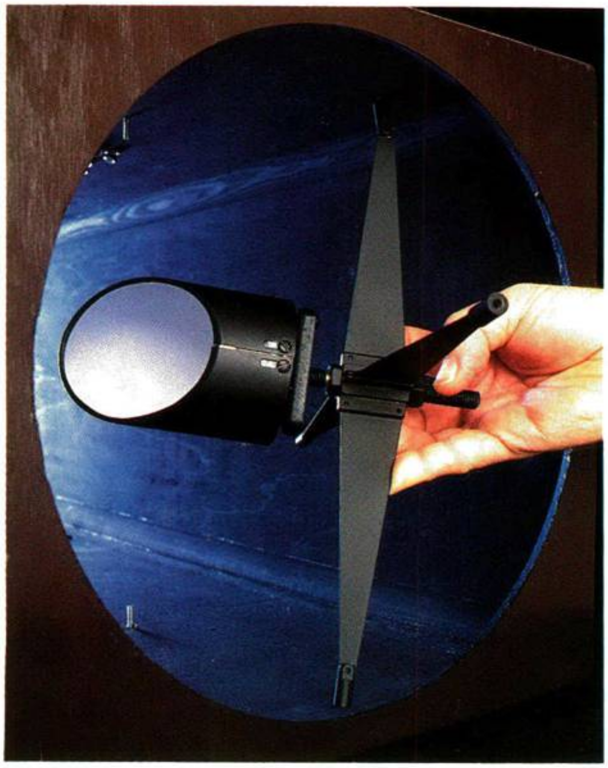
**HOLDING THE MIRROR** in place is the job of the mirror cell. Three nylon acorn nuts evenly support the mirror's weight, and nylon washers keep the mirror from tipping out of the cell. The threaded rods tip the mirror about two axes going through the ball joint.



**THE MIRROR PIVOTS** about a ball joint that rides in countersunk holes. A long screw passing through the wood bead locks the mirror support to its base.

## Parts List for Mirror Cell

| | |
|---|---|
| 1 | 12" x 12" plywood, 3/4" thick |
| 1 | 11" x 11" plywood, 3/4" thick |
| 1 | 3/4" wood dowel, 8" long |
| 1 | 7/8"-diameter wood bead |
| 3 | 8x32 roundhead screws, 1/2" long |
| 3 | 8x32 roundhead screws, 1" long |
| 2 | 8x32 threaded rods, 24" long |
| 8 | 8x32 nuts |
| 4 | #8 washers |
| 3 | #8 thick nylon washers, 3/4" diameter |
| 3 | 8x32 nylon acorn nuts |
| 2 | 8x32-threaded knobs |
| 5 | 8x32 threaded inserts |
| 4 | 10x32 flathead screws, 1" long |
| 2 | 10x32 screws, 2" long, with knob heads |
| 6 | 10x32 threaded inserts |
| 1 | 1/4x20 flathead screw, with washer and 2 nuts |
| 2 | brass mending strips, about 5/16" x 1 1/2" |
| 2 | 5/32" universal joints (try a hobby shop) |
| | flat black paint |



**INSTALLING THE DIAGONAL MIRROR** is a simple task. Drill holes in the center of each side and then secure the spider with screws. Center the diagonal by measuring the distances between the tube sides and the rod supporting the diagonal mirror.

through the base at its center. Choose the rougher of the two sides of the base to face toward the focuser and countersink the hole on this side.

Laying out the mirror support is slightly more complicated. First mark the center of the square. Draw two circles, one of radius 3 1/4" and the other of radius 5". Draw three legs 120° apart and 1 1/2" wide from the center until they hit the 3 1/4" circle. Cut out the segments between the legs. Opposite each leg, draw a tab 2" wide extending about 1" beyond the 5" circle. Pick one of these tabs as one of the two alignment directions. Along a 90° angle to this radius, draw another tab outside the 5" circle. This acts as the second direction of alignment. Cut the mirror support from the 11" square, keeping outside the tabs and the 5"-radius circle.

Next you need to mark and drill nine holes in the support. Drill an 11/16" hole in each leg, 3 1/4" from the center of the support. In two tabs, drill an 3/4" hole 5 1/8" from the center. In the tab also used for alignment, drill a 3/4" hole 5" from the center and an 11/16" hole 5 1/2" from the center. In the second alignment tab, drill an 11/64" hole 5 1/2" from the center. The last one is a 5/16" hole at the center of the support. Countersink both sides of this hole.

Use the two center holes to align the mirror support and base and then turn the support piece until the two alignment tabs are centered along two adjacent edges of the base. With an awl, mark the point in the base below each of the two 11/64" holes in the tabs. Drill 13/64" holes in the base at these locations. About 1/2" inside these holes along a radius through the center of the base, drill 1/4" holes.

Next measure the thickness of your primary mirror. It will probably be 1" thick. Cut three pieces of 3/4"-diameter wood dowel with lengths equal to the thickness of the support, mirror, and nylon acorn nut, plus 1/32" (about 2 7/16"). Glue the dowels in the 3/4" holes in the support with the end sticking out of the mirror side.

Once the glue dries, cut each dowel along its length, using the 5" circle as a guide and then cut off the inside part of the split dowel. Test fit the primary mirror. It should slide easily into place inside the three dowels with no binding. There should be just enough room to slide a postage stamp between the mirror and each dowel. Use a rasp to lightly file the dowels until the mirror fits just right. Then drill a 13/64" hole in the top of each dowel. Remove the mirror and turn the support over. Fasten two brass mending strips 1/2" inside the two holes in the alignment tabs. These act as a bearing surface for the push screws and should line up with the 1/4" holes in the base.

With both pieces cut out and all the holes drilled, it's time to paint the mirror cell. Don't bother sanding the pieces because rough surfaces absorb scattered light better. Just remove any splinters or jagged edges and then paint all surfaces with flat black paint (don't get any paint in the holes).

The first step in assembling the cell is to install the three-point support for the mirror. From the backside of the mirror cell, pass a 1"-long 8x32 roundhead screw through the hole in each leg. Fasten it with a nylon acorn nut. Next, install threaded inserts in the three 11/64" holes in the dowels. Check that the top of each insert is flush with the top of the dowels.

Install 10x32 threaded inserts in the 1/4" holes and 8x32 inserts in the 11/64" holes in the base.

The next step is making the ball joint that holds the two pieces of the mirror cell together. Drill a 1/4" hole through the center of a 7/8"-diameter wood bead. This acts as the pivot of the alignment system. Pass a 2"-long 1/4x20 flathead screw through the center hole of the mirror support, through the bead, and then through the base. The bead should rest in two of the countersinks. Place a washer on the screw and secure it loosely with two nuts. If you can't get both nuts on, drill deeper countersinks for the bead. The nuts should be tight enough that the wood pieces can't slide along the screw but not so tight that the cell can't easily pivot about the bead.

For the mirror adjustments, cut 8x32 threaded rods to 6 1/4", 7 1/2", 15", and 17 1/4" lengths. Screw two nuts and place a washer on the 7 1/4" and 15" rods. Insert these rods through the holes in the alignment tabs of the mirror support, slide on another washer on each rod, and screw on two more nuts. Screw these rods into the inserts in the base and then adjust the nuts until the mirror support is spaced evenly above the base. Attach universal joints to the free end of the rods above the mirror support. Screw the 2"-long 10x32 knob-head screws through the inserts in the base until the screws touch the mending strips.

The nearly completed mirror cell is now ready to install in the mirror box.

### Installing the Mirror Cell

Remove the door of the mirror box and set it aside. Place the mirror cell about 1" inside the bottom edge of the box. Check that the base is square to all three sides of the mirror box using a try square and then clamp the cell in place. In the two opposing sides of the box, drill two holes through each side into the mirror cell base. The 5/32" holes sit 1 3/8" from the end of the box and 2" from the edges. Drill the holes deep enough so they go completely through the box sides and just start to bore into the base of the mirror cell. (Use tape wrapped around the drill as a depth indicator.) Countersink these holes for flathead screws.

Unclamp the mirror cell and remove it from the box. Drill 1/2"-deep 1/4" holes at the four locations on the base just marked. Screw 10x32 threaded inserts into these holes.

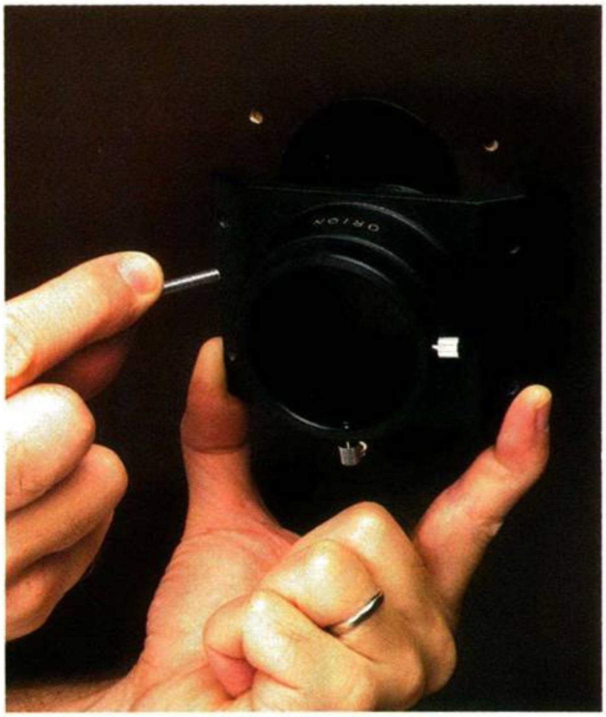
On a side of the mirror box to the right of the removable door, drill two 3/16"-diameter holes. The holes start about 1" from the top of the box (from the top of the sides, not the 1x4 collar); one is in the center and the other 1" from the side. Drill the holes at a 25° angle, that is, nearly parallel to the side of the box.

Now is a convenient time to install the primary mirror in its cell. Be careful not to touch the mirror surface as you lower it carefully into the cell. Hold it in place with nylon washers and 1/2"-long 8x32 screws in the dowels.

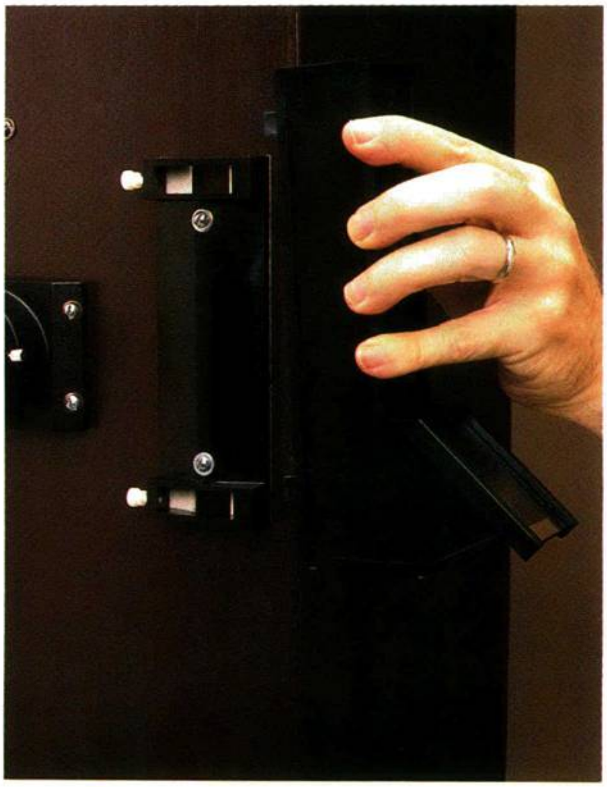
Replace the mirror cell in the box and secure it with 1 1/4"-long 8x32 flathead screws. Screw a knob on one end of the 6 1/4" and 17 1/2" rods and slide them through the holes in the mirror box. Insert the ends in the universal joints and test that turning the knobs will adjust the mirror position. Take a break, the rest of the parts installation will be easy.

### Getting in Focus

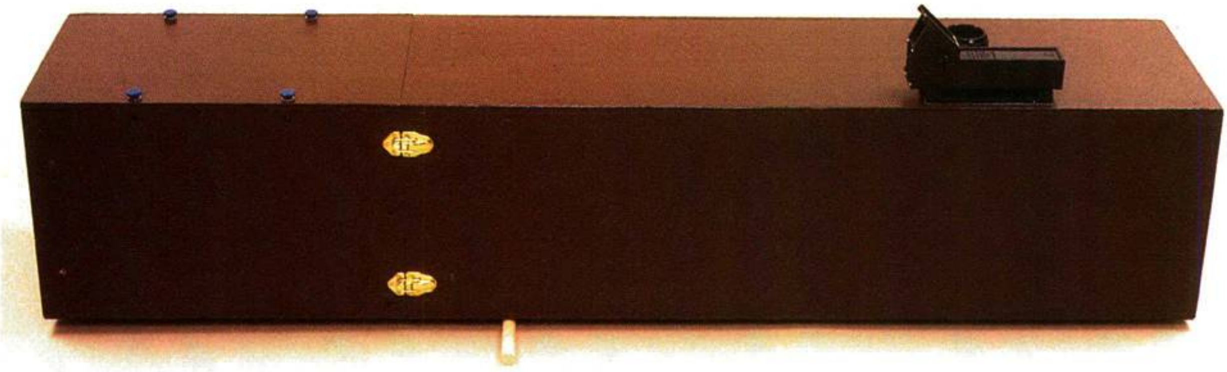
Installing the focuser is the next step. Assemble the



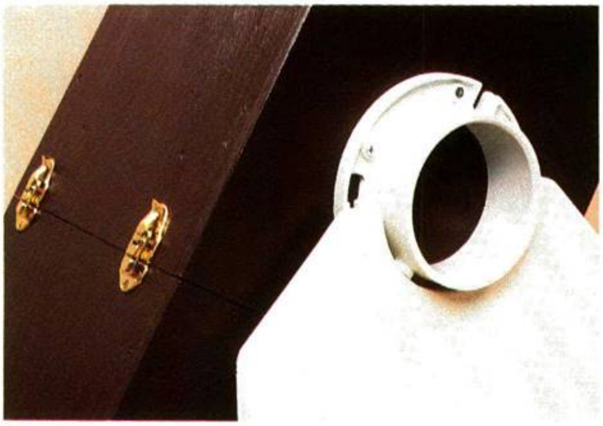
**THE FOCUSER SITS DIRECTLY ABOVE** the diagonal mirror. A large 2 3/8" or 2 1/2" hole is needed to accommodate the draw tube of a 2" focuser. Machine screws secure the focuser to the tube.



**MOUNTING THE TELRAD FINDER** is easy. Just place the base parallel to the edge of the tube and screw it in place. Alignment of the finder with the scope's field of view requires just a few twists of the screws on Telrad's back.



**BALANCING THE SCOPE** on a dowel or broomstick determines the placement of the flanges used for the altitude bearings.



**THE SCOPE ROCKS UP AND DOWN** in altitude on two closet flanges. Nylon gliders nailed inside the rocker box can keep the tube from scraping the sides.

tube and decide which side of the tube will hold the focuser and finderscope. Choose a side that doesn't have draw catches to avoid rubbing the catches against the side of the rocker box. Place this side down on your workbench. As mentioned in part one of this series, the diagonal-to-focus distance is 9". Thus the primary mirror-to-diagonal distance is the focal length minus this number (56" minus 9", or 47"). Mark a spot exactly in the center of the tube's side 47" from the mirror. (Use the edge of a piece of paper to drop a line from the mirror's surface down to the tape measure.) Drive a finishing nail through the tube wall to mark this spot on the outside of the tube.

A 2" focuser requires a 2³/₈" clearance hole. The easiest way to cut this is with a hole saw mounted in a drill. (A 2¹/₂" *hole saw is more common and will also work.)* Once the hole is cut, center the focuser in the hole and mark the locations for its mounting holes with an awl. Drill ¹¹/₆₄" holes at these locations, replace the focuser and fasten it with 1¹/₄"-long 8x32 roundhead screws.

Next comes the installation of the diagonal. Follow the directions of the manufacturer carefully to install the mirror in its diagonal holder and the support (often called a spider). Installing the support goes roughly like this: Measure the distance from the center of the diagonal to the center of the spider (about 4¹/₂"). Mark this distance from the center of the focuser away from the primary mirror on the outside of the tube.

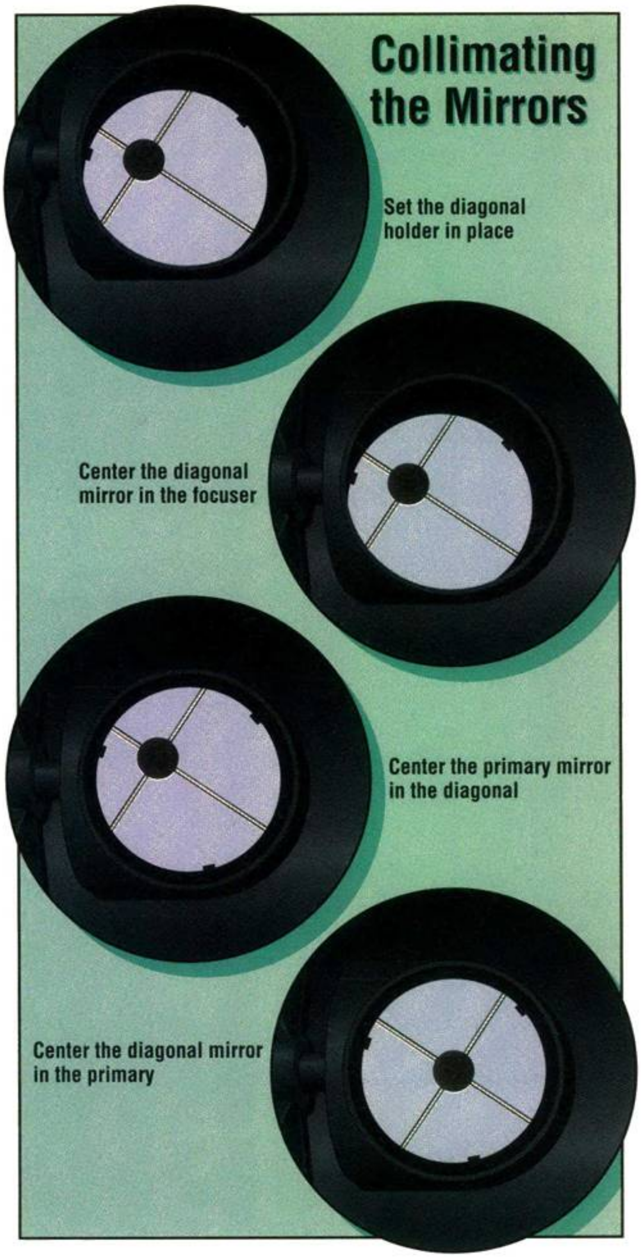
Get an 8"-wide strip of paper about 60" long. Wrap this around the tube, ensuring that the edges of the overlapping sections of paper are flush and that the starting end of the paper aligns with the mark on the tube. Mark the upper layer of paper at the overlap. Take the paper off the tube and fold it in half between the end and the mark made at the overlap. Then fold it in half again.

Place the paper on the tube and realign the overlap with the mark on the tube. The edge of the paper should also just touch the mark on the tube. Mark the tube at the three paper folds. Check that these locations are centered in each side and then drill an ¹¹/₆₄" hole at each spot. Install the spider using 1¹/₄"-long 8x32 screws, checking that the spider is roughly centered in the tube. The screws should be tight enough that the metal legs of the spider sound a "thwong" when plucked. Don't let the legs twist because that will increase diffraction of the image, resulting in lower contrast images.

The next item to install is the finderscope. The PortaScope uses a Telrad reflex sight popular with deep-sky observers. First, choose where you want the finder. A convenient place is near the eyepiece, on the right side of the tube for right-eyed observers and on the left for observers who use their left eye. I prefer to have the reflex mirror of the Telrad even with the focuser for easy viewing.

Remove the sight from its base and place the base on the tube where you want the finder. Align the base so it's parallel with the edge of the tube. Using the two holes in the base as a guide, drill ¹¹/₆₄" holes through the tube. Secure the base with 1¹/₄"-long 8x32 roundhead screws. Replace the sight on its base and wait until the scope is collimated. Then you can find a star in the scope and use the adjustment screws on the Telrad to bring the field of view into alignment with that of the scope.

**ALIGNING THE MIRRORS** requires adjustment of the screws on the diagonal holder and the push-pull screws on the mirror mount. Center the diagonal as seen through the focuser tube, adjust the diagonal so the primary mirror appears centered, and then align the primary until the diagonal's reflection appears centered.


Collimating the Mirrors
Set the diagonal holder in place
Center the diagonal mirror in the focuser
Center the primary mirror in the diagonal
Center the diagonal mirror in the primary

With the focuser, finder, and all of the optics in place, the final construction step is to mount the two closet flanges on the tube. The first step in this process is to balance the tube. (Be sure to place a medium-weight eyepiece in the focuser.) Place a wooden dowel or broomstick on the floor. Set the tube perpendicularly on top, shifting the tube's position until it balances on the rod. This point will be about 5½" above the division in the tube. Mark this line on a side without the draw catches. Measure the distance from the tube division to this line and mark a line on the opposite side of the tube. Use the lines to center the closet flanges and secure the flanges with 1"-long #8 wood screws.

## Test Drive Your Scope

With construction finished, the long awaited day of "first light" through the scope is here. But first check out the alignment of the optics so your first view of the Moon or a distant galaxy isn't a disappointing one. A good article on how to collimate your scope's mirrors appeared in the April 1992 ASTRONOMY, but the outline below describes how to roughly collimate a scope.

Take the scope outside during the daytime. Remove the eyepiece from the focuser and install a collimating aid. (You can make your own by drilling a tiny hole in the center of the top of a 35mm film canister and cutting off the bottom of the can.) Looking through the hole in the collimating aid, you'll see the diagonal mirror, a reflection of the primary mirror in the diagonal and, within this reflection, a reflection of the diagonal mirror.

The first step is to center the diagonal mirror so it shows the entire primary mirror. You may need to center the spider, move the diagonal on its support toward or away from the primary mirror, and then fine tune the diagonal's position by using the three screws on the back of the diagonal support.

Once the diagonal is adjusted so the primary appears centered in it, it's time to adjust the primary. Loosen the push screws at the back of the primary mirror cell. Using the adjustment rods, move the primary until the reflection of the diagonal mirror appears centered in the primary mirror. Gently tighten the push screws to lock this adjustment into place.

Then wait for nightfall. Take your PortaScope outside and peer at the Moon, Mars at opposition, the Orion Nebula, the Andromeda Galaxy, and the countless star clusters scattered along the Milky Way from Cassiopeia to Canis Major. Somehow the view will be a little better because you made the scope yourself. ☐

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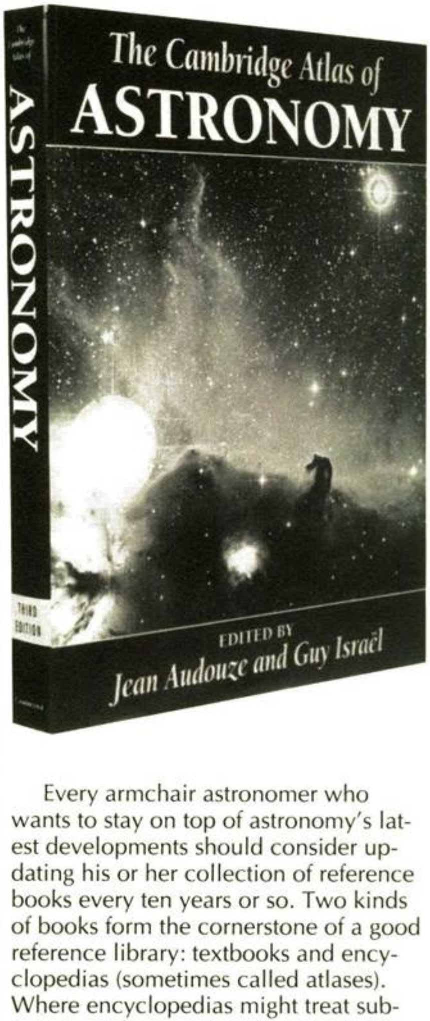
## ASTRO BOOKS

# Astronomy in a Nutshell

**The Cambridge Atlas of Astronomy, Third Edition**
Edited by Jean Audouze and Guy Israel, (Cambridge University Press, 1994), ISBN 0-521-43438-6, 475 pages, hardcover, $90.



Every armchair astronomer who wants to stay on top of astronomy's latest developments should consider updating his or her collection of reference books every ten years or so. Two kinds of books form the cornerstone of a good reference library: textbooks and encyclopedias (sometimes called atlases). Where encyclopedias might treat subjects topic by topic, textbooks attempt to fit subjects into a comprehensive picture. Some textbooks group material into learning modules, complete with exercises that get into the minute detail necessary for complete comprehension. On the other hand, encyclopedias broadly survey astronomy for the interested layman. The third edition of *The Cambridge Atlas of Astronomy* (last updated in 1988) provides such a survey, giving the state of astronomy as it stood in the later part of 1993.

*The Cambridge Atlas of Astronomy* involves the efforts of close to 30 European astronomers, with half again as many people (drawn mainly from the Royal Greenwich Observatory) helping to translate the French edition into this English edition. The oversized book ($10^{1}/_{2}$" x $14^{1}/_{2}$") is divided into sections that deal with the Sun, the solar system, the stars and the Galaxy, and extragalactic space. A final, catch-all section called "The Scientific Perspective" contains a wide range of subjects, including cosmology and the history of astronomy.

Even if you already own the second edition of *The Cambridge Atlas of Astronomy*, published in 1988, you might want to consider shelling out the 90-odd dollars for this edition. Though roughly two-thirds of edition three is material rolled over from 1988, the rest is new, including a rather extensive treatment of Neptune and Venus that reflect Voyager 2 and Magellan results. The write-up on asteroids also has information on Gaspra, thanks to the Galileo spacecraft's 1992 flyby (unfortunately the spacecraft's spectacular encounter with Ida is not included).

Information added since the 1988 edition includes new details about galactic and extragalactic astronomy, specifically chapters on Supernova 1987A, protoplanetary systems, current ideas on the nature of dark matter, and what quasars reveal about the universe's scale. The book's bibliography is also extensively revised and expanded. Unfortunately this comes at the glossary's expense, which in the new edition has been condensed and confusingly combined with the index under the index's heading.

Because the atlas is oversized, pictures and wonderful illustrations have great visual impact, which makes it fun to browse through the book. Illustrations are also well-designed to mesh with the material being discussed. Insofar as the writing is concerned, I wouldn't classify reading through it as recreational activity. As is typical of most encyclopedias, the narrative is formal and can seem weighty at times. Clauses within sentences are liberally connected to one another by semicolons. One criticism I have lies in the book's typography: The type averages eight points. Reading such tiny type is challenging, particularly in the captions, which often stretch across two columns.

Those minor quibbles aside, *The Cambridge Atlas of Astronomy* delivers a

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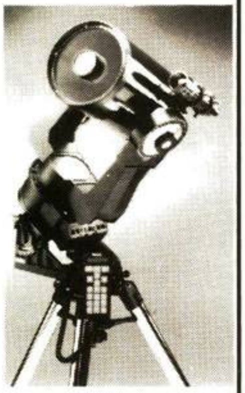

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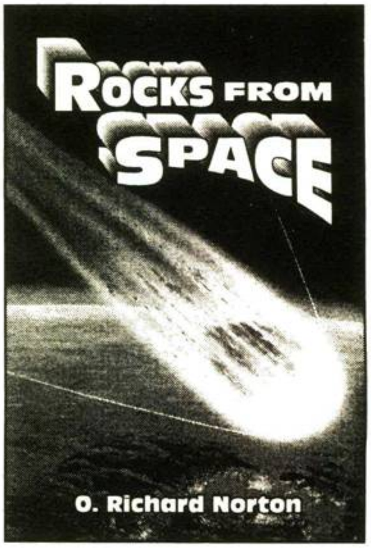
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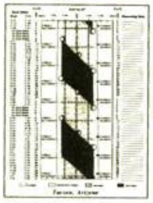

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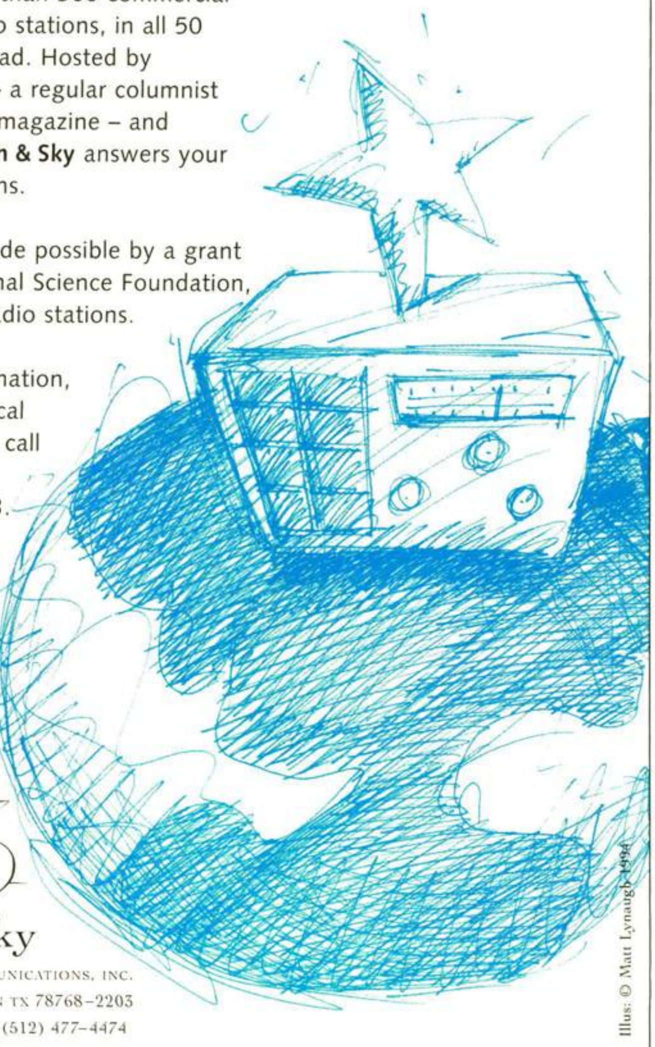

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splendid tour of astronomy, complete with some of the latest information and images. No doubt edition four will have all sorts of science derived from the new, improved Hubble Space Telescope, Clementine's mission to the Moon, and Galileo's work at Jupiter. Until then, this third edition of *Atlas* does an exceptional job at hitting a moving target called "modern astronomy." — *John Shibley*

## More New Books

### The Planet Observer's Handbook

Fred W. Price, (Cambridge University Press, 1994), ISBN 0-521-44257-5, 410 pages, hardcover, $34.95.

Fred Price sets out to address three audiences in *The Planet Observer's Handbook*. For the armchair astronomer, there's the history of solar system exploration and an overview of solar system science today. The casual observer finds general advice on how to observe the planets and what to look for. For the serious planetary observer, Price outlines distinct areas of study for each planet and provides advice on projects that include planetary drawing, photography, and photometry. The middle of the book is organized by planet from Mercury out to Pluto, with introductory information (such as how to select a good planetary scope) at the front of the book and more advanced topics (photometry of asteroids) at the back. At the end of each chapter is a book list for further reading.

### Stairway to the Stars

Barry Parker, (Plenum Books, 1994), ISBN 0-306-44763-0, 344 pages, hardcover, $27.95.

On top of Mauna Kea, a dormant volcano in Hawaii, sit nine telescopes, one of which, the 10-meter (394-inch) Keck telescope, is the largest in the world. Subtitled *The Story of the World's Largest Observatory, Stairway* is a history of how this observatory complex came to be and what research is done with it today. With this history are explanations of the objects that astronomers study. Parker relates what it's like to work on Mauna Kea and introduces us to some of the scientists who use the scopes. The end of the book details current construction projects and future plans: The 8-meter Gemini telescope, a second 10-meter scope (Keck II), an 8.3-meter Japanese scope called *Subaru* (the Japanese name for the Pleiades), and a radio telescope array that uses six 6-meter dishes. □

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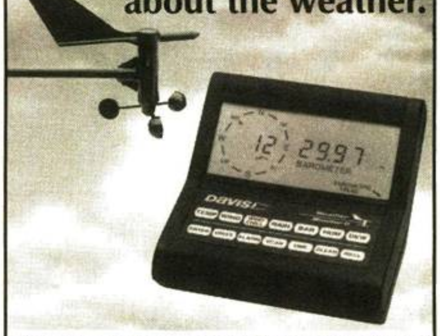

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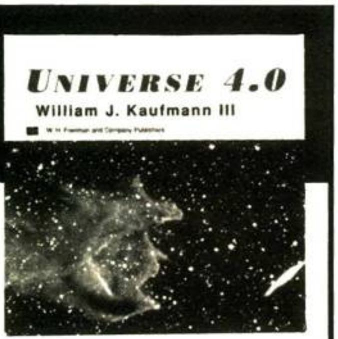

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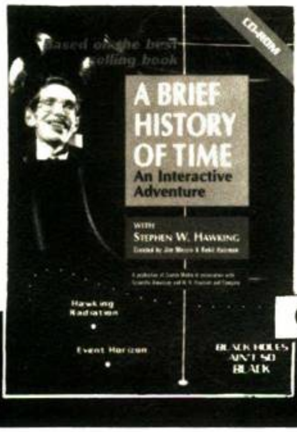

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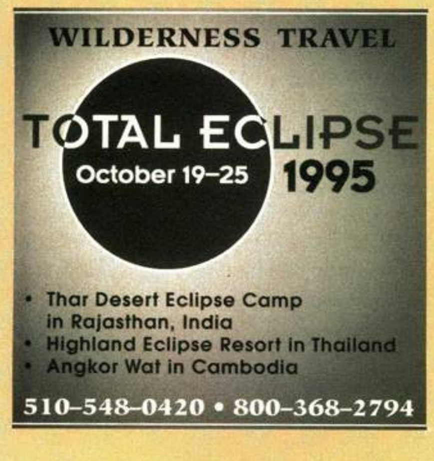

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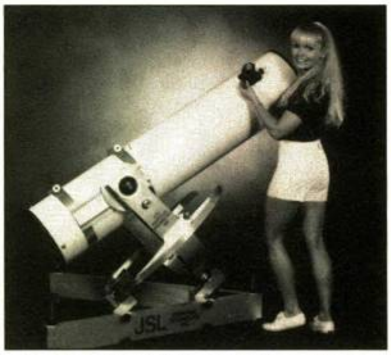

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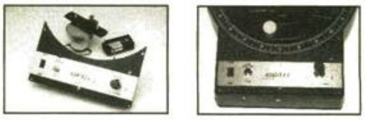

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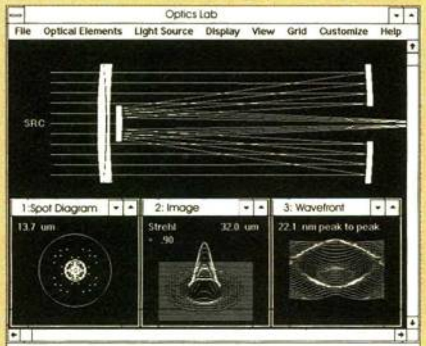

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# NEW PRODUCTS

### Self-guided CCD Cameras

Santa Barbara Instruments Group's ST-7 and ST-8 cameras contain two CCD chips: one for guiding, the other for imaging. The imaging array in the ST-7 is 768 x 512 pixels, while the ST-8 has a 1536 x 1024 pixel array. The pixels are square-shaped and measure 9 microns. Both cameras have an electromechanical shutter, a 16-bit A/D converter, and a one stage thermoelectric cooler that cools the chip below ambient temperature. A Windows program included with every camera controls guiding and imaging functions and supports image processing, photometry, and astrometry.

Santa Barbara Instruments Group, P.O. Box 50437, Santa Barbara, CA 93150, (805) 969-1851, fax (805) 969-4069. ST-7: $2,450; ST-8: $6,450.

### 0.965" Barlow Lens

Celestron offers owners of telescopes that use 0.965" eyepieces a redesigned 2x Barlow lens that is 2⅞" long and weighs two ounces. Its fully multicoated achromatic lens offers a clear aperture of 21 millimeters.

Celestron, 2835 Columbia Street, Torrance, CA 90503, (310) 328-9560, fax (310) 212-5835. $70.

### Astronomy Newsletter

*Clear Skies* is a quarterly publication with articles on observing, sketching, and photographing the sun, moon, and deep-sky objects. Feature stories also give tips on building equipment. Guest columnists include Peter Taylor, solar recorder for the Association of Lunar and Planetary Observers, and David Cortner, author of the syndicated newspaper column "City Skies."

Sky Bear Publishing, 10464 Clairemont Mesa Blvd. #222, San Diego, CA 92124. 1 year subscription: $19, payable by check or American Express.

### 20x100 Binoculars

Swift's Model 848 20x100 Titan waterproof binoculars incorporate BaK4 prisms and feature multicoated optics housed in a nitrogen-filled body to reduce internal fogging. The eyepieces individually focus, offer a 27 mm eye relief, and are set at 45° angles for viewing convenience. Built into the center-mounted carrying handle is a tripod mounting socket. Optional accessories include extendable glare shields, a 3 x 12 finder with illuminated crosshairs, and a shockproof carrying case. The binoculars have a limited lifetime warranty.

Swift Instruments, Inc., 952 Dorchester Ave., Boston, MA 02125, (617) 436-2960, fax (617) 436-3232. Model 848 20x100 Titan: $3,350; glare shield (item 848H): $364; finder (item 848FS): $399; carrying case (item 848BC): $289.90.

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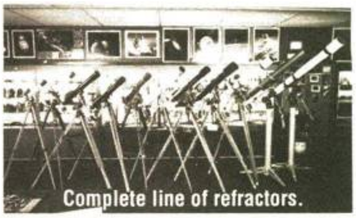
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# PRODUCTS

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Bushnell introduces three compact "Rotary Power" achromatic refractors. Model 78-1445 (top) has a 60mm f/15 objective and comes with a rotary eyepiece holder, a 2x Barlow, a Moon filter, an erecting prism, and a complement of 20mm, 10mm, and 4mm eyepieces. Model 78-1546 (bottom) has an objective lens identical to the objective in a 78-1445 but comes equipped with a 3x Barlow, a star diagonal, a 1.5x erecting prism, and 5mm and 20mm eyepieces. Both scopes are mounted on a slow-motion altazimuth head. The model 78-1337 telescope (not pictured) has the same accessories as the 78-1445 but comes with a 60mm f/7.5 objective and lacks fine-adjustment features in its altazimuth head. All scopes come with a 5x25 finder, 0.965-inch eyepieces, an adjustable tripod, a guidebook, and a nylon carrying bag.

Bausch & Lomb Sport Optics Division, 9200 Cody, Overland Park, KS 66214, (800) 423-3537. Model 78-1445: $239.95; Model 78-1546: $229.95; Model 78-1337: $199.95.

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## Meteor Video

*Meteorites*, a two-part program produced by the Austrian Broadcast Corporation and aired on The Learning Channel, now comes in a boxed set of two videotapes. The program explores the physical nature of meteors, their mention throughout human history, and the large impact that some believe caused a mass extinction on Earth 65 million years ago. The two VHS tapes have a combined playing time of 84 minutes.

Atlas Video, Inc., 4915 St. Elmo Avenue, Suite 305, Bethesda, MD 20184, (301) 907-0030, fax (301) 907-9049. $29.95.

## Flip-down Mittens

FingerMit convertible mittens feature flip-back caps that expose all five fingers. They are made from wool and have leather palms; the caps have Thinsulate insulation. The mittens are available in small (5-8) and large (9-12) sizes and come in black, rag gray, and camouflage colors.

Tempo Glove Mfg. Co., 3820 West Wisconsin Ave., Milwaukee, WI 53208, (414) 344-1100, (800) 558-8520, fax (414) 344-4084. $26.95.

*This department presents new product announcements issued by their manufacturers. Product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers should send their product announcements to the attention of John Shibley.*

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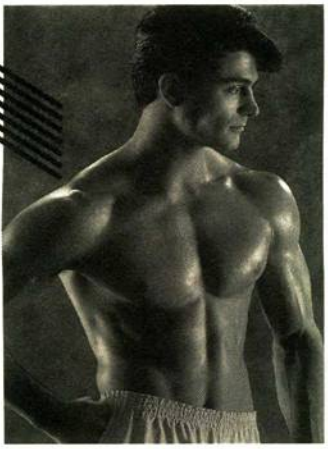

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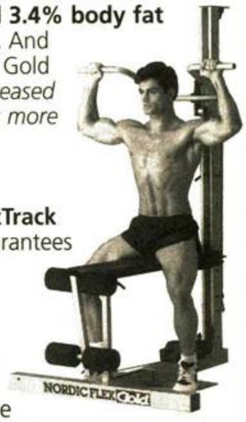

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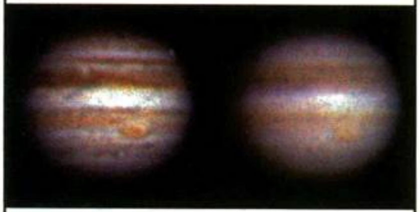
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JUPITER 1994

These photos were taken just 3 minutes apart with the same 10" scope; 22 sec at F/140 on color slide film. Note tiny Europa on the upper right, its shadow on the left, and cloud detail *inside* and around the Great Red Spot,... when the AO-2 is turned on!

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## ASTRO BYTES

# New Software

### Astronomica

Hyper-Quest, Inc., 1718 Main Street, Suite 333, Sarasota, FL 34236, (813) 365-(9800), fax (813) 365-8324. Price: $69.95. Minimum requirements for PC version: 33 MHz 80386-based computer, 4 MB of memory, DOS 5.0, Windows 3.1, SuperVGA display, CD-ROM drive (MPC compatible), MPC-compatible sound card, and a mouse; Mac version: Macintosh II, LC, or Performa computer, System 7.0, 4 MB of memory, color monitor, and CD-ROM drive.

This multimedia package of programs aims its content at kids aged 9 to 14. The main component of the three programs is a mystery that takes place at a mountaintop observatory. Sarah's father, an astronomer, is missing. Sarah and her friends, who include the user, break into his laboratories to search for clues and find they have to unscramble his experiments in order to reach him. (The CD-ROM permits sophisticated 3-D animation of the journey through the labs.) The detectives encounter science puzzles such as "Things that Disappear," "Strange Lights and Colors," and "Birth and Death of a Universe" and must uncover the fate of the universe, without the night watchman catching them.

Hyper-Quest

An encyclopedia containing illustrations, photographs, and text provides information needed to solve the puzzles. It also serves as a stand-alone resource for young astronomers. The remaining component of *Astronomica* is a trivia game that has hundreds of questions about astronomy.

### Messier Observer's Guide

Larry Kalinowski, 15674 Flanagan, Roseville, MI 48066. Price: Shareware, $5 for version 2.0 with 50 objects and $24.95 for version 4.0 with 109 objects. Minimum requirements: 80286-based computer, DOS 2.11, VGA display, 384 KB of free memory, and hard drive with 3.3 MB of free space.The program supports a mouse.

Want to earn the Astronomical League's Messier certificate by finding 50 or more of the deep-sky objects in Messier's catalog with binoculars or at least 70 objects with a telescope? For each deep-sky object in the Messier catalog, the *Messier Observer's Guide* displays a map showing where to find the object and an illustration of what it looks like as seen through a small scope or binoculars. Long-exposure photos don't accurately show what the eye will see, so these views help prepare observers to spot these sometimes elusive objects. The text lists the object's Messier number, common name, object type, position, and brightness. It also states what constellation the object appears in and the best month to look for it.

The program presents the maps and illustrations as a series of 109 "slides." Although some Messier lists include 110 objects, the *Messier Observer's Guide* lists 109 and excludes the controversial M102. Users can step forward or backward through the slides one at a time, or they can go to a particular Messier object. A search facility helps find objects by magnitude, position, type of object, or its *New General Catalogue* number. An automatic slide show mode cycles through each object in order of Messier catalog number, a feature that some clubs might find of interest for an Astronomy Day display.

Users can print the display using the DOS GRAPHICS command (requires DOS 5.0 or better). The displays, however, can't be modified for use by Southern Hemisphere observers or to correspond to views through star diagonals. Observers wanting more information about the Astronomical League's Messier observing certificates should contact Kathy Machin, 4845 N. Smalley Avenue, Kansas City, MO 64119.

### Expert Astronomer CD-ROM

Expert Software, 800 Douglas Road, North Tower, Suite 750, Coral Gables, FL 33134-3128, (800) 759-2562, fax (305) 448-2074. Price: $49.95. Minimum requirements: 80486SX-based computer, Windows 3.1 (running in enhanced mode), 4 MB of memory, hard drive, CD-ROM drive, 8-bit sound card, mouse, and VGA display with 256 colors. A double-speed CD-ROM drive and 8 MB of memory are recommended.

*Expert Astronomer CD-ROM* is a Windows-based program that functions the same way *Expert Astronomer* does for the Macintosh. As a planetarium-type program, it can display roughly 12,000 objects. (See the review in the July 1993 AstroBytes for more information about the planetarium aspects of this program.)

What makes this version of *Expert Astronomer* different from the others is the multimedia presentation. It contains 40 minutes of color video clips showing, for example, Moon landings and shuttle launches. The program can also display more than 500 still images of celestial objects and 1,000 text articles. Hypertext capability allows users to jump to other text articles by using search features or by clicking on highlighted key words in an article. The four main topics in the multimedia portion include the solar system, deep-sky astronomy, observing the sky (about optical and radio observatories), and space exploration.

### From Your Monitor to the Wall

After all that image processing on a CCD image, wouldn't it be nice to have a copy to show friends without firing up the computer? Pinecone Imaging Corp. (P.O. Box 55296, Portland, OR 97238) has a solution called *PhotoQ.* After users process images with their favorite image-processing program, they use PhotoQ to assemble the images as digital layouts in combinations such as one 8x10 print, two 5x7 prints, four 4x5s, six 3x4s, or nine wallets. Then they send the images to Pinecone via modem or by floppy disk, and the company will convert the digital files into photographs. The cost per 8x10 sheet is $14.95, plus a $2.50 shipping and handling fee per order. *PhotoQ* supports most image formats, including BMP, EPS, FITS, GIF, JPEG, LNX, PCD, ST4, ST6, and TIFF.

To get the free program *PhotoQ,* dial the electronic bulletin board at (206) 253-6149, call (800) 636-5998 to order the program on a floppy disk (costs $5 for shipping and handling), or e-mail to pineconeic@aol.com. □

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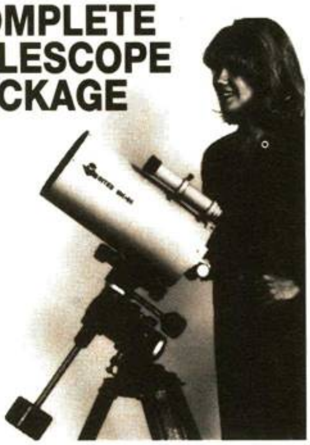

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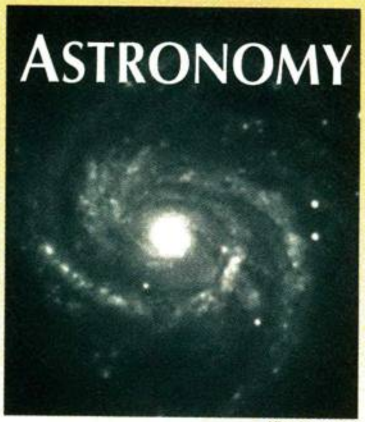

Kim Zussman

### THE FIRST NEW PLANET
Carl Sagan tells the story of Uranus, the first planet found since antiquity.

### HOW FAR TO VIRGO?
The discovery of Cepheid variables in the Virgo cluster of galaxies adds fuel to the fierce debate over the size and age of the universe.

**CHALLENGING PLANETARIES** A modest backyard scope reveals subtle details in the nebulous remnants of dying stars.

**POLARIS, THE CODE-BLUE STAR** Why has the North Star's variable heart stopped beating?

**EARLY SPRING OBSERVING** March is the perfect time to spot a very young Moon and the subtle glow of the zodiacal light.

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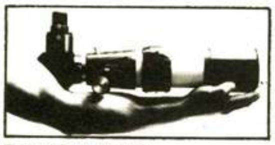

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**February 4**
**Wagman Winterfest**, Wagman Observatory, northeast of Pittsburgh, Pennsylvania. Sponsored by the Amateur Astronomers Association of Pittsburgh. Contact John Holtz, (412) 262-3452.

**February 4-5**
**2nd Annual Northwoods Winter Starfest**, Hobbs Observatory, Fall Creek, Wisconsin. Sponsored by the Chippewa Valley Astronomy Society. Contact Ray Forsgren, 4856 Inlet Drive, Chippewa Falls, WI 54729.

**February 16-21**
**AAAS Annual Meeting**, Atlanta, Georgia. Sponsored by the American Association for the Advancement of Science. Contact the AAAS Meetings Office, 1333 H Street, N.W., Washington, DC 20005, (202) 326-6450.

**February 27-March 5**
**Winter Star Party**, near Key West, Florida. Sponsored by the Southern Cross Astronomical Society. Contact Bob or Sharon Grant, 5401 SW 110 Avenue, Miami, FL 33165, (305) 595-8778.

**March 13-17**
**26th Lunar and Planetary Science Conference**, NASA Johnson Space Center, Houston, Texas. Cosponsored by the Lunar and Planetary Institute and the Johnson Space Center. Contact LeBecca Simmons, LPI Publications and Program Services, 3600 Bay Area Boulevard, Houston, TX 77058-1113, (713) 486-2158.

**March 24-27**
**MEPCO '95**, Violau, Germany. Sponsored by the Working Group of Planetary Observers of Germany. Contact Wolfgang Meyer, Matrinstrasse. 1, D-12167 Berlin, Germany or Daniel Fischer by e-mail at p515dfi@mpifr-bonn.mpg.de or fax 49-2244-80298.

**June 24-25**
**Universe 95**, College Park, Maryland. Sponsored by the ASP and ASTRONOMY magazine. Contact the Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112, (415) 337-110 or fax (415) 337-5205. ☐

*Clubs, please submit announcements at least four months before the date of the event. Readers, include a self-addressed, legal-sized envelope with your request for information.*

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# RESOURCES & PHOTOFACTS

### Compelling Capella (page 48)

*Stars*, by James Kaler, (Scientific American Library, 1992). An excellent introduction to the life cycles and characteristics of stars.

*Burnham's Celestial Handbook*, by Robert Burnham, Jr., (Dover, 1978). Relates older observations and how astronomers uncovered Capella's binary nature.

### Daytime Star (page 66)

*Guide to the Sun*, by Kenneth Phillips, (Cambridge University Press, 1992). A primer on how the Sun works and how to observe it.

### Star Clusters (page 76)

*The Universe from Your Backyard*, by David J. Eicher, (Cambridge University Press, 1988). Deep-sky objects presented by constellation.

*Webb Society Deep-Sky Observer's Handbook*, Vol. 3, edited by Kenneth Glyn Jones, (Enslow Publishers, 1980). Descriptions and drawings of star clusters.

### 10-inch PortaScope (page 78)

"Better Mirror Cells," by Robert E. Cox, *Telescope Making*, No. 6, Winter 1979/80. Describes different designs for mirror cells and how to improve a mirror cell you already have.

"How to Collimate Your Telescope," by Michael Porcellino, ASTRONOMY, April 1992. Details how to align scope optics.

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**p. 49:** L. H. Price, 50mm lens at f/1.8, Kodachrome 64, 8-min. exposure; **p. 52:** Randall Wehler, 28mm lens at f/2.8, Ektachrome 200, 5-min. exposure using a barn-door photo platform; **p. 54:** John Cordiale, 20mm lens at f/2.8, Fujichrome 1600 film, 40-second exposure; **p. 59:** Don Parker, 16-inch Newtonian at f/48, Spectra Source Lynxx CCD camera, January 6, 1993; **p. 60, both:** Kevin Bolam, 205mm lens at f/2.8, Kodacolor 400 film; **top:** 20-min. exposure on November 18, 1989; **bottom:** 21-min. exposure on November 24, 1989; **p. 62:** Luke Dodd, 300mm lens at f/4, hypered Fujicolor 400 film, 10-min. exposure; **p 63:** Martin C. Germano, 8-inch f/5 Newtonian, hypered Tech Pan film, 65-min. exposure; **p. 66:** Dan Gordon, 4-inch f/8 refractor stopped down to f/32 and fitted with a Daystar T scanner oven prominence Hα filter with a 2x relay barlow; 1/15 second on Tech Pan 2415 film developed in MWP-2; **p. 69:** Gerard Therin, 4-inch f/5 refractor stopped down to f/30 and fitted with a metal-coated glass solar filter, 1/1000 second on Tech Pan 2415 film; **inset:** Gordon Garcia, 5.2-inch f/8 refractor fitted with an aluminum-coated mylar solar filter and a #58 green filter, 1/1000 on Tech Pan 2415 developed in HC110, dilution B, for 5 min. at 68° F; **p. 70:** Don Trombino, 6-inch f/12 stopped down to f/30 and fitted with an Hα filter, 1/60 second on Tech Pan 2415 developed in HC110, eventually transferred to Fujichrome 50; **p. 71:** Rick Dilsizian, 8-inch f/10 Schmidt-Cassegrain fitted with a metal-coated glass solar filter, 1/30 second on Kodachrome 64; **pp. 72-75:** Glenn Gombert and John Chumack; **p. 76:** M52 (NGC 7654) by Jack Newton, 16-inch f/5, 12 min., Fujichrome 400; **p. 77, top left:** NGC 7789 by J. C. Mirtle, 8-inch f/6, 30 min., hypersensitized Tech Pan 2415; **top right:** NGC 457 by Lee Coombs, 10-inch f/5, 5 min., Kodak 103a-0 film developed in MWP-2 for 9 min. at 20° C, printed on Ilfospeed #5 paper; **center:** M103 (NGC 581) by Lee Coombs, 10-inch f/5, 5 min., Kodak 103a-0 film developed in MWP-2 for 9 min. at 20° C, printed on Ilfospeed #5 paper; **bottom left:** NGC 869 and NGC 884 by Mark Killow, 5-inch f/5.9 refractor, 30 min., Fuji Super G 400; **bottom right:** NGC 1528 by Lee Coombs; 10-inch f/5, 10 min., Kodak 103a-0 film developed in MWP-2 for 9 min. at 20° C, printed on Ilfospeed #5 paper; **p. 109, top:** Jim Primrose, 50mm lens at f/1.4, Fuji Super HG 400 film, 60-second exposure taken in August 1994; **middle:** James R. Foster, 14-inch SCT at f/7, Fuji Super HG 400 film, 20-min. exposure on September 5, 1994; **bottom:** Tony and Daphne Hallas, 12.5-inch f/7 reflector, Fuji Super HG 400 film, composite image of two 50-min. exposures; **p. 110, top:** James R. Foster, 14-inch SCT at f/7, Fuji Super HG 400 film, composite image of 65-min. and 75-min. exposures; **middle:** Martin C. Germano, 14.5-inch f/5 reflector, hypersensitized Tech Pan film, 100-min. exposure; **bottom:** Bob and Janice Fera, 11-inch SCT at f/10, hypersensitized Fuji Super HG 400 film, composite of 40-min. and 60-min. exposures; **p. 111, top:** Bill and Sally Fletcher, 16-inch f/4.5 reflector, hypersensitized Tech Pan film, composite image of 65-min. red, 90-min. green, and 125-min. blue exposures; **bottom:** Gerald Rhemann, 4-inch f/7 refractor, hypersensitized Fuji Super HG 400 film, composite image of two 60-min. exposures; **p. 112:** Dave Petherick, 8-inch f/8 reflector, composite of 15 CCD images made on September 18, 1994, with a Cookbook 245 CCD camera and a filter stack consisting of 0.9 and 0.6 neutral density, #47 violet, #80A violet, and #23 red filters. ☐

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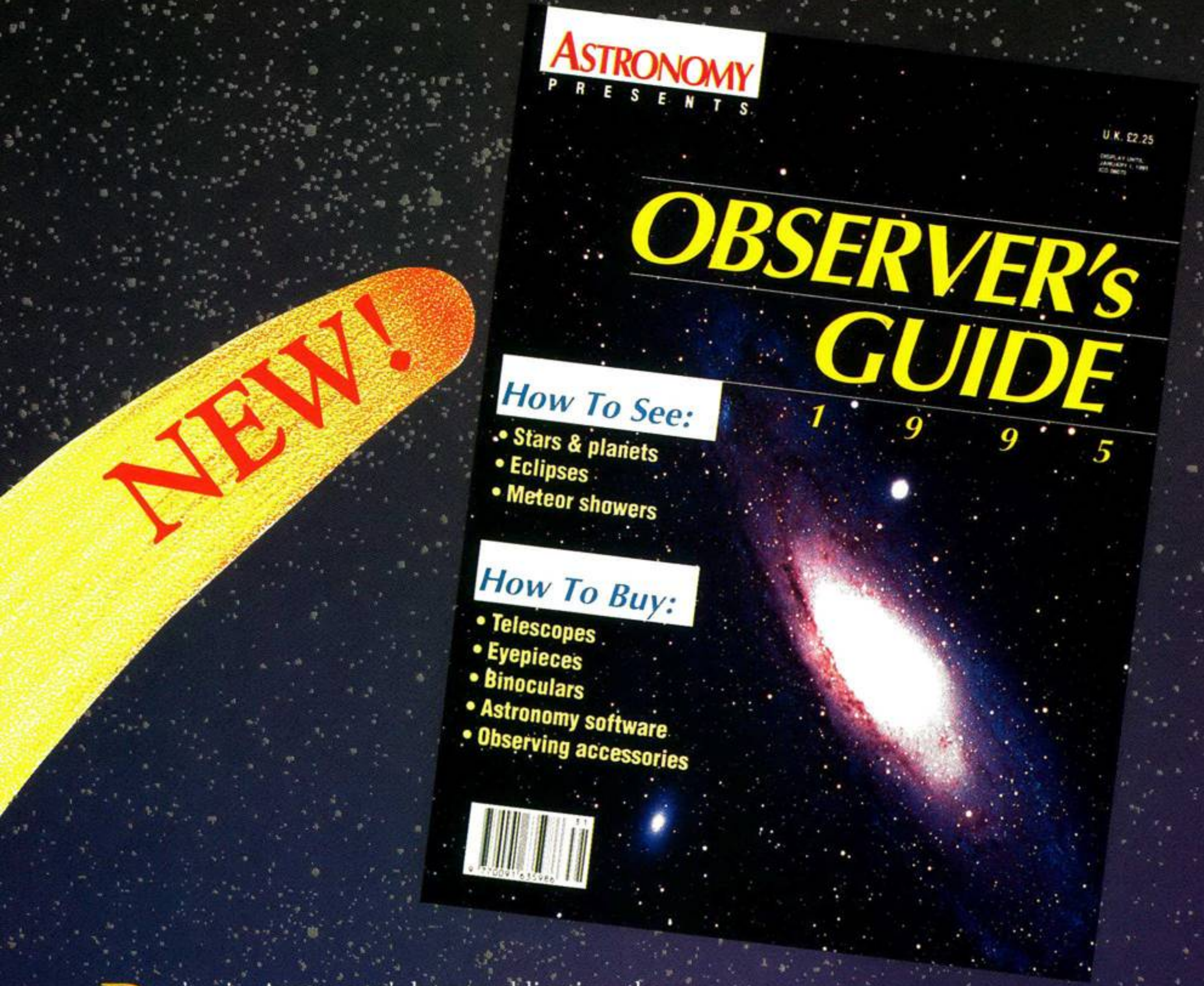

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| Discoverer Case | 44.95 |
| **Tamrac Case** for Discoverer | 14.95 |
| Camera Mount | 18.95 |
| Car Window Mount | 34.95 |

**ELITE PC**

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| 611548PC #ELITE with Zoom E.P. | Call |

**NEW PREMIER**

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| Premier HDR 15-45 x 60 | Call |

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|---|---|
| **Spacemaster** | 147.95 |
| New **Spacemaster ED** | 294.95 |
| **Spacemaster** Rubber Armored | 161.95 |
| **Spacemaster** with 15-45x, Table Tripod & Case | 243.95 |
| **Spacemaster** Rubber with 15-45x Table Tripod & Case | 256.95 |

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|---|---|
| 15, 20, 25, 40 & 60x EP | 33.95 |
| 22x Wide Angle | 48.95 |
| 15-45x Zoom Eye Piece | 81.95 |
| Camera Mount | 29.95 |
| **Baush & Lomb Elite** 77mm Spotting Scope | Call |
| 77mm S. S. Elite | Call |

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| 55mm 2" | Call |
| 40, 32mm 1 1/4" | Call |
| 26, 21, 17, 13mm 1 1/4" | Call |
| 10.5, 7.4mm, 1 1/4" | Call |

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| New 15mm 1 1/4" | Call |
| New 27mm 1 1/4" | Call |
| 22mm 1¼" | Call |
| 35mm 2" | Call |
| Panoptic Barlow Interface 2" | Call |

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| 2.5X, 1.8X 1 1/4" | Call |
| Big Barlow 2x 2" | Call |

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|---|---|
| 20mm Type 2; 2" | Call |
| 16mm Type 2; 2, 1 1/4" | Call |
| 12mm Type 2; 2, 1 1/4" | Call |
| 13mm 2" & 1 1/4" | Call |
| 9mm 2" & 1 1/4" | Call |
| 7mm 1 1/4" | Call |
| 4.8mm 1 1/4" | Call |

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|---|---|
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| **Rich Field Kit** w/New 55 Plossl 2" S.D., Adapt, 2" to 1 1/4" Adapt | 329.95 |
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**PARACORR COMA CORRECTORS**

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|---|---|
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| 2" | Call |

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Genesis™-sdf

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| **GENESIS SDF** Fluorite-APO | Call |
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| **GENESIS-SDF Outfit** w/Sky Tour Computer & Gibraltar Mt. | Call |

**PRONTO 70mm Aperture f/6.4 w/ED Glass**

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|---|---|
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| PRONTO w/1.25" Star Diagonal & 21mm Plossl | Call |

**MOUNTS & ACCESSORIES FOR TELE VUE REFRACTORS**

**New SKY TOUR Computer–Call for details**

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| **GIBRALTAR MOUNT** | **434⁹⁵** |
| Gibraltar Mount with Sky Tour Computer | Call |
| **Starbeam** ."Red Star" Projection Finder | Call |
| **Piggy-Cam** .Camera Adapter | 41.95 |

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| Car Bat. Adpt. C5+,C8+ Ultima | 27.95 | Series 6 Filter Set | 69.95 |
| Accs Cs. | 49.95 | Stereo Binocular Viewer | 449.95 |
| Barlow 1 1/4" 2x MC | 54.95 | Star Diag 1.25" MC | 47.95 |
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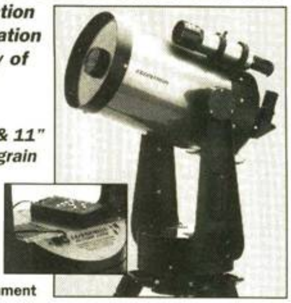

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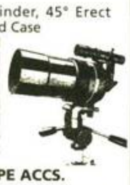

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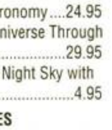

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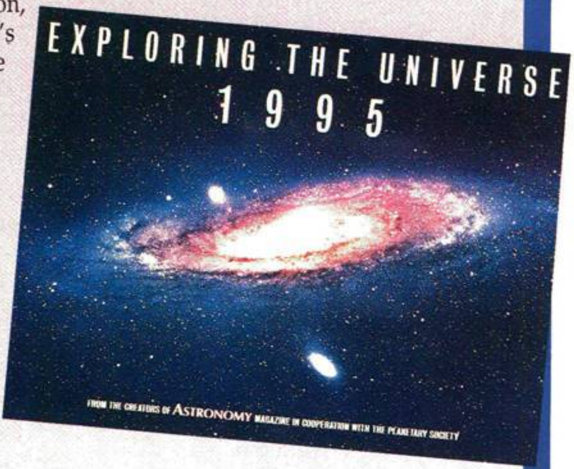
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# READER REPORTS

## Meteors: Thumbs Up or Thumbs Down?

Reports from meteor showers past have inundated our offices. Last year saw a wide range of showers from the spectacular Perseids to little observed events like the Alpha Aurigids. Here's a brief synopsis of how meteor fans felt about the last several major meteor showers.

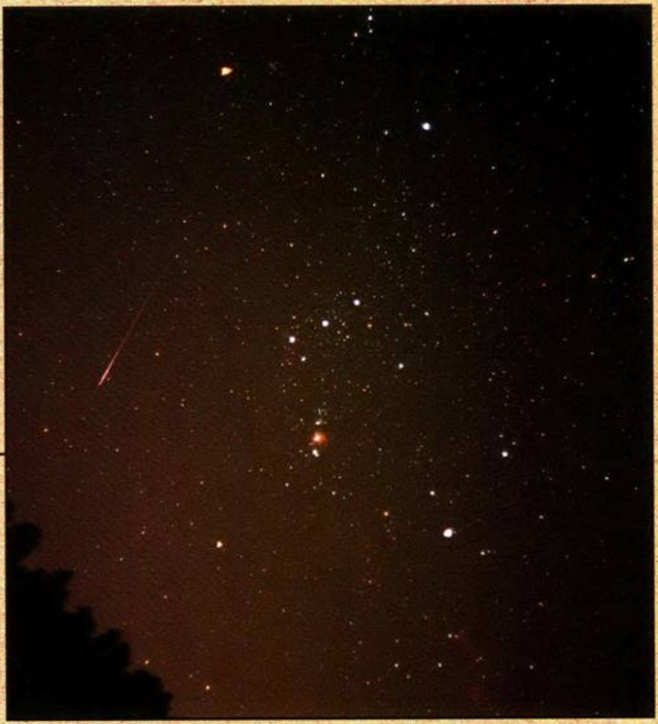
**Quadrantids**, January 3, 1994. "They were a big disappointment for me. No fireballs to get excited about." — *George J. Zay, La Mesa, California.*

**Lyrids**, April 22, 1994. "During three hours of observing I detected 25 Lyrids and 22 sporadics. The best was a –5-magnitude fireball that left a train visible for sixteen seconds." — *George J. Zay.*

**Eta Aquarids**, May 4/5, 1994. "This year's Eta Aquarids were neither a barnburner nor a disappointment." — *George J. Zay.*

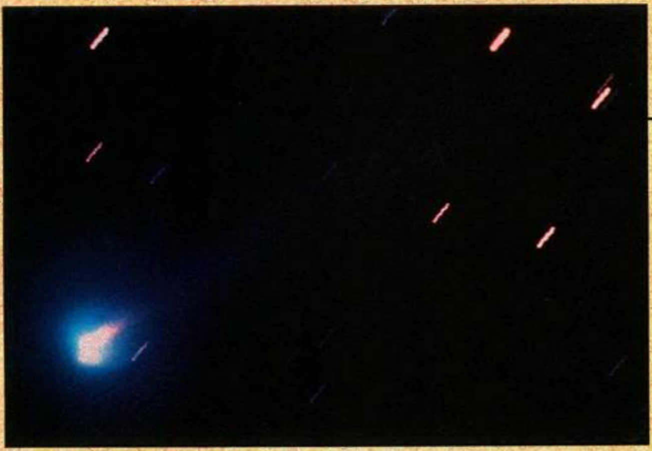
**Perseids**, August 12/13, 1994. Alister Ling and Bruce McCurdy organized a Perseid watch at the Mount Kobau Star Party in British Columbia. "I counted 726 Perseids in a 15-hour span over four nights. The highest burst of activity occurred when I logged 22 meteors in ten minutes on August 10." — *Bruce McCurdy.*

**Alpha Aurigids**, August 31, 1994. "It's not a major shower. But this year Robert Lunsford and I may have witnessed a small outburst on the night of August 31/September 1. In a 45-minute period we observed 13 Alpha



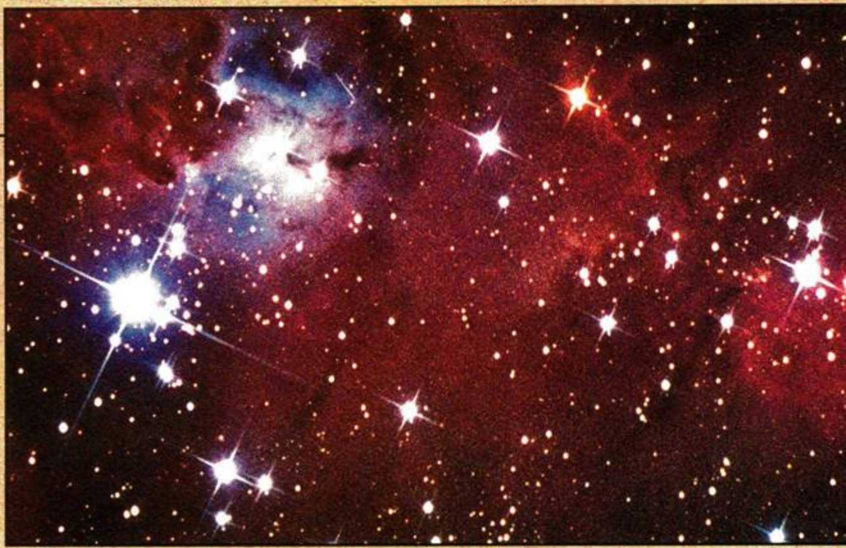
**A Bright Perseid Visits Orion**

by Jim Primrose (50mm lens at f/1.4, Fuji Super HG 400 film, 60-second exposure taken in August 1994)



**Comet Machholz 2 (1994o)**

by James R. Foster (14-inch SCT at f/7, Fuji Super HG 400 film, 20-minute exposure on September 5, 1994)



**The Cone Nebula (NGC 2264)**

by Tony and Daphne Hallas (12.5-inch f/7 reflector, Fuji Super HG 400 film, composite image of two 50-minute exposures)

Aurigids. The average magnitude was 1.8, and several left a train that could be seen for several seconds." — *George J. Zay.*

**Possible Triangulid Shower**, September 10/11, 1994. "I traveled to the mountains of West Virginia to help confirm the existence of a possible new meteor shower in the Aries-Triangulum area, as reported in Reader Reports (January 1994). From the clear skies of Mathias, West Virginia, I logged 22 meteors from a radiant just south of Alpha Trianguli in five hours on two nights. The average magnitude was 2.5." — *George W. Gliba, Greenbelt, Maryland.*

**White Spot on Saturn.** On August 13, 1994, astronomers at the Pic du Midi Observatory in France detected a conspicuous white spot in Saturn's southern hemisphere, the first major white spot on Saturn since the Great White Spot of 1990. The spot appeared centered at about 30° longitude and between 57° and 61° south latitude, extending some 12° across.

A sequence of images made with the 1.06-meter telescope at Pic du Midi and the 0.41-m telescope at Barcelona, Spain, showed the origin of the storm near the planet's south pole and its subsequent spreading and darkening through the first three weeks of September.

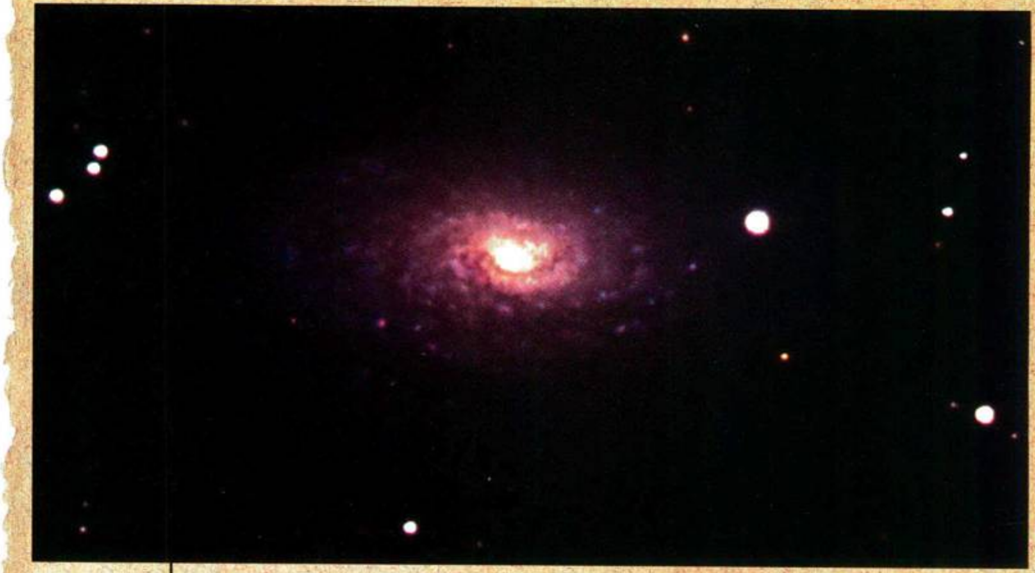
Throughout October a number of observers noted subsequent activity on the Ringed Planet.

Have any readers observed this spot? □

---

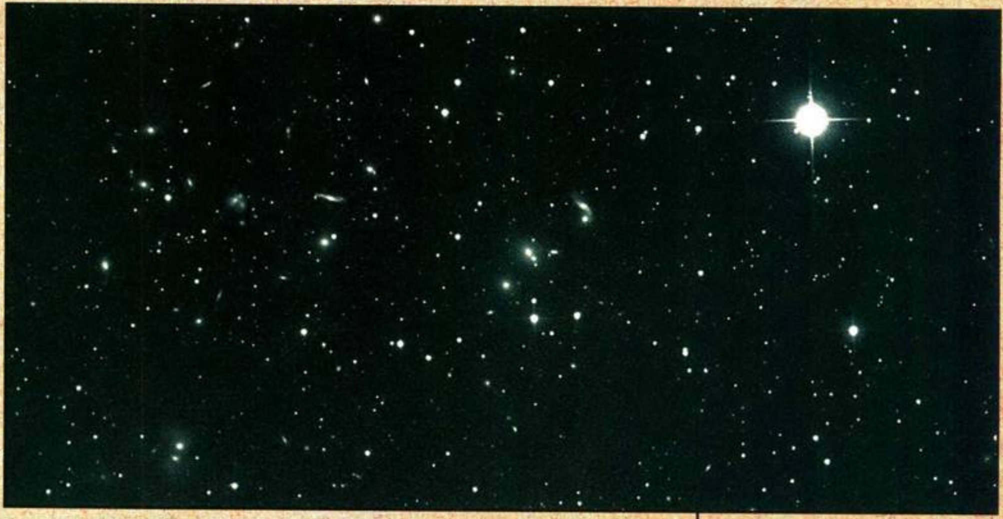
*ASTRONOMY wants to hear about your observations of the sky. Send reports, sketches, and photographs to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187.*

*Please label each photo with name, address, and social security number. You may send written reports via the Internet to: 72000.2704 @CompuServe.com.*



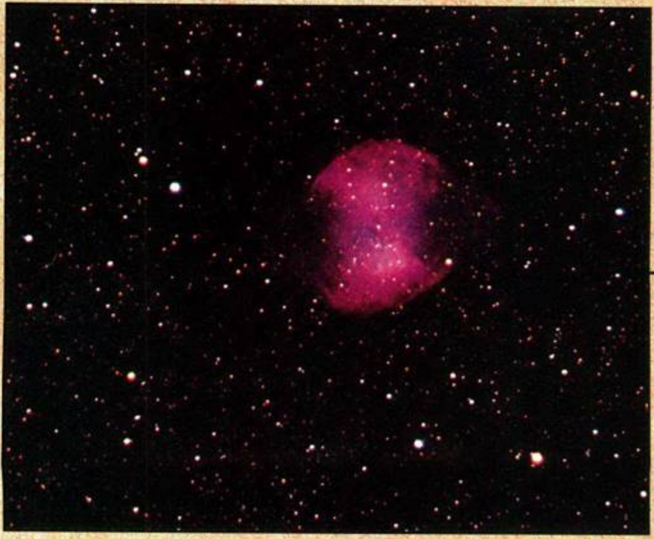
**Galaxy M63 in Canes Venatici**

by James R. Foster
(14-inch SCT at f/7, Fuji Super HG 400 film, composite image of 65-minute and 75-minute exposures)



**The Hercules Cluster of Galaxies**

by Martin C. Germano
(14.5-inch f/5 reflector, hypersensitized Tech Pan film, 100-minute exposure)



**The Dumbbell Nebula (M27)**

by Bob and Janice Fera
(11-inch SCT at f/10, hypersensitized Fuji Super HG 400 film, composite of 40-minute and 60-minute exposures)

**The Veil Nebula (NGC 6992-5)**

by Bill and Sally Fletcher (16-inch f/4.5 reflector, hypersensitized Tech Pan film, composite image of 65-minute red, 90-minute green, and 125-minute blue exposures)

**The Andromeda Galaxy (M31)**

by Gerald Rhemann (4-inch f/7 refractor, hypersensitized Fuji Super HG 400 film, composite image of two 60-minute exposures)

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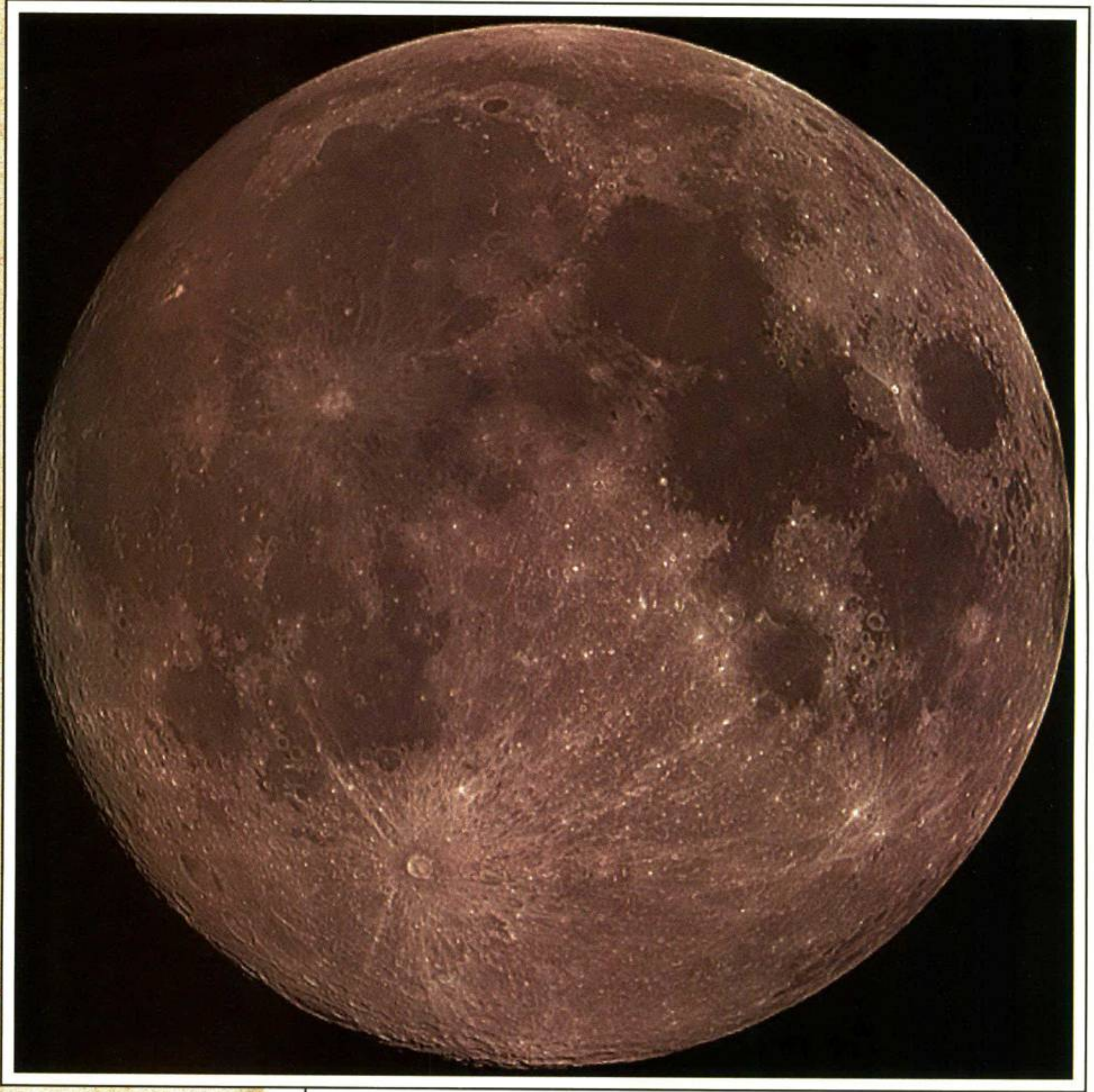


### The Moon in CCD Vision

by Dave Petherick

(8-inch f/8 reflector, composite of 15 CCD images made on September 18, 1994, with a Cookbook 245 CCD camera and a filter stack consisting of 0.9 and 0.6 neutral density, #47 violet, #80A violet, and #23 red filters)

"The filters were stacked to reduce the Moon's intensity and allow the camera's normal exposure mode, which results in the maximum number of gray levels without saturation," says Petherick.

"I processed the images using CB245PIX and used a triangular unsharp mask to bring out the detail. I then opened the images in Aldus Photostyler, composited and trimmed them, and produced the result you see."

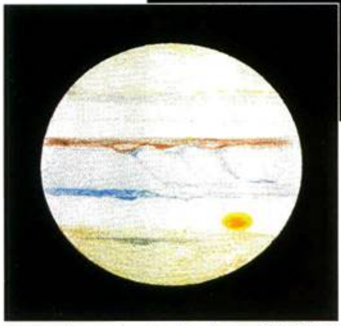
# "NO OTHER EYEPIECES...SATISFY ME NOW."

— The following unsolicited letter from a fellow enthusiast is dated Mar. 30, 1994. It is printed unedited and with permission.

Dear Mr. Nagler,

***"I thought it long overdue that I write to give my impressions of your Nagler eyepiece designs.*** *I say 'long overdue,' because I bought my first Nagler (a 7mm) back in 1984. The reason for the purchase was that earlier that year I had invested in a Celestron C-11 and a 4" Fluorite, F/9 refractor. I thought that the stated objectives of the Nagler design — long eye-relief and a wide, highly corrected field of view, would exploit the full potential of a telescope with 2,800mm focal length, and the imaging capacities of a fine refractor. I was not disappointed. Soon after came the fantastic 9mm and 11mm Naglers and then the 4.8mm for the refractor.*

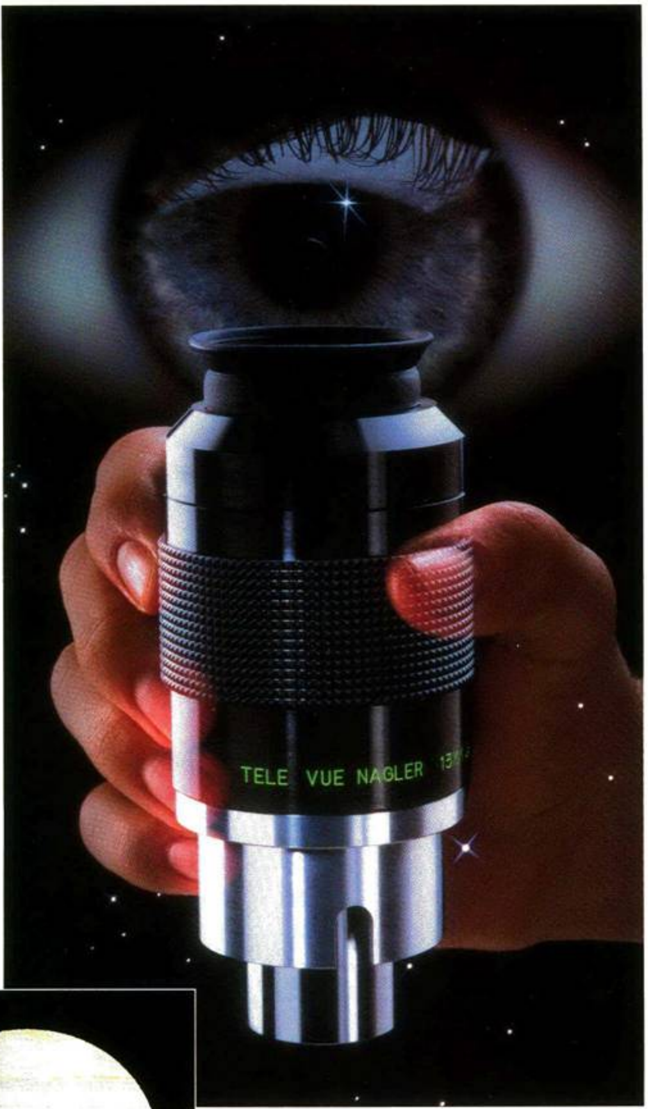
***These eyepieces have given me my most rewarding hours spent at the telescope.*** *My main interest is in the planets which I draw and give lectures on at our local school and observatory. The observation of the planets requires painstaking hours spent at the eyepiece. The Naglers suit my purposes exactly.*



Drawn by Mr. Toohey with 12 N2

*When the Type 2s were introduced onto the market I could not resist them. I purchased the 16mm and 12mm models. The 20mm seemed too large, heavy and costly, so I left it alone. These were the same reasons for not buying the 13mm (apart from the fact that by then I owned a 12mm Type 2). However, earlier this year, after years of looking through other people's 13mm and 20mm Naglers, I finally decided to take the plunge myself.* ***So now I own a full set of Naglers*** *(including the wonderful 11mm which despite many offers, I will not part with).*

*When I remember what eyepieces for the amateur market were like before the introduction of the Naglers (like looking down a drain pipe, or 60° fields, with astigmatism and severe edge of field aberrations),* ***it is clear that your designs have taken us a quantum leap forward. No other eyepieces, in the Naglers' range of focal lengths, satisfy me now.***



*Many of my fellow planetary observers say that conventional field eyepieces are sufficient. In a way they are right; good Plössls, for example, produce superb images. However, I believe the extra eye-relief, the huge field of the Naglers, coupled with marvellous image correction and the impression that* ***the telescope simply gets out of the way,*** *all add up to a delightful psychological difference when using the Naglers. One feels more involved, more present to what one is viewing.*

*Over the years I have found that amateur astronomers can be fairly stubbourn people in somehow defending their choice of equipment. Next thing you know they upgrade what was once, in their view, the very best available.* ***Only good products stand the test of time. For me, the Naglers are such a product.*** *Not only have they remained with me; I have kept buying more of them!*

*To some extent, astronomy, and particularly amateur astronomy, is about emotion and the involvement of the imagination.* ***I have to say that Nagler eyepieces have captured my imagination.*** *As well as giving pride of ownership, Naglers are immensely satisfying and a joy to use.*

*The little instruction sheet that comes with the eyepieces says that you wish the user 'years of exciting viewing with these eyepieces, and welcome comments on your experiences with them.' So you asked for it. After a decade of superb images (many of which remain etched on my memory; most of which I have recorded on paper) I felt it timely to share my comments and to thank you for your contribution to amateur astronomy."*

Yours Sincerely.
Christopher A Toohey

Christopher Toohey, Australia

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